HIRDLS

TC-HIR-57H

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: J. G. Whitney Date: 14 July 1997

Subject/Title : **SYSTEM PERFORMANCE REQUIREMENTS AND ALLOCATION TABLES (SPRAT)**

Description/Summary/Contents:

- The SPRAT has been expanded to include more detailed descriptions of the flow-down and allocation of the major IRD requirements. Section 5 (new section) contains an Excel table showing the traceability of each requirement as it flows from a source document, through the SPRAT, to a destination document.
- A significant addition to Section 3 tabulates the Instrument Modes and Submodes, and includes an outline of a possible post-launch Instrument Activation Sequence.
- Change Log:- substantive changes since release of rev. G dated **25 AUG 95** are listed in Section 1.1
- Minor wording changes and corrections are not indicated

Keywords: Instrument; System; Performance; Requirement; Subsystem; Flowdown; Alignment; Boresight; Error_budget; Field_of_view; Jitter; Pointing; Cooling

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SECTION 1

INTRODUCTION

1.1 CHANGE LOG

General: Each text para. still carries a header line showing the source doc, destination doc(s) and relevant budget table(s). The doc. para. numbers have been deleted from the header lines, and now appear in a separate table in section 5.

1.2.1.a Scope: reference added to post-launch data processing; refers also to the Excel table in section 5.

1.2.1.b "Objectives" section added.

1.2.3 Updated and expanded to show top-level document flowdown chart (replaces Fig. 1-1)

1.4 Reference document list updated; several entries deleted where no longer referenced in body of SPRAT; list divided into three groups for source docs, destination docs and ref. docs

1.5 "Specification for the High Resolution Dynamics Limb Sounder (HIRDLS)" added

1.6 Abbreviations & acronyms: now refers to TC-HIR-149B only

2.1.4 Deleted

2.2.3 New para; gives revised instrument position knowledge requirement

2.2.5 Detail added

2.4.15 25%-of-NEN IRD requirement changed to 100%

2.9.15 "(44000 + Z) +/- 5%" changed to "46000 +/- 10%"

3.3.23 New para

3.4.2 "Fault detection and protection" item added to list

3.4.3 No longer requires SAIL routines and tables in ROM.

3.5.1)
3.5.3)
3.5.5) New Mode and Submode tables compiled, with definitions

3.5.9 Preliminary Activation Sequence [new]

3.5.17 Launch Submode requirements defined [replaces old 3.5.2]

3.5.19 et seq. [unchanged, but renumbered]

3.6 New section on fault detection and protection

3.8.9 New requirement (motor stall survival)

3.9.3, 3.9.5 New paras, specifying maximum accumulated particulate contamination levels

3.9.11 New venting and filtering requirements added

3.9.21 New para. defining system-related requirement for shipping environment.

4.2, etc. All references to VERTIFOV Budget deleted. The vertical FOV budgets are in effect a family of optical error budgets associated with the design, manufacture and alignment of the telescope. They do not need to be addressed in the SPRAT.

4.2 (new) CONTAMIN(ation) Budget: allocates allowable particulate contamination levels at various program stages; derived from OUTFIELD Budget.

4.3 OUTFIELD Budget: 25%-of-NEN IRD requirement changed to 100%.

4.16 COOLMARG Budget: re-written to include more information, showing which numbers are flowed into ITS and which are for reference; updated

5. New traceability summary table added.

1.2 SCOPE, OBJECTIVES & FORMAT OF THE SPRAT

1.2.1 Scope

The following kinds of technical requirement relating to the HIRDLS instrument are addressed by the SPRAT, viz:

a) IRD performance requirements, many of which need to be ALLOCATED to instrument and instrument subsystem parameters, to spacecraft parameters, to pre-launch calibration or to post-launch data processing. These requirements are in Section 2 of the SPRAT. Where appropriate, a BUDGET TABLE in Section 4 shows the currently allocated values for these parameters. The SPRAT does NOT include those IRD requirements which apply directly to instrument subsystem hardware and can be explicitly verified prior to calibration; such requirements flow directly into the ITS.

b) Requirements in any of the source documents listed below which require MODIFICATION or INTERPRETATION and cannot be directly flowed down to the appropriate ITS or other lower-level document.

c) SYSTEM ENGINEERING requirements and constraints, some of which do not appear in higher-level HIRDLS Requirements Documents, are included in Section 3 of the SPRAT and have been flowed down to the appropriate ITS or other lower-level document. Where the requirement is based on a higher-level document, the source ref. is given in the header line.

The flow-down summary table in Section 5 lists ALL IRD paragraphs and how they have been categorised for SPRAT purposes. It also shows which other source document requirements have been addressed in the SPRAT.

1.2.2 Objectives

The objectives which the SPRAT are intended to achieve are:-

a) to take into account every HIRDLS "mission" requirement other than those which apply directly to instrument subsystem hardware and can be explicitly verified prior to calibration (per 1.2.a above);

b) to break down each such requirement into its component parts as they may affect or apply to the design and pre-calibration performance of the instrument itself, to the pre-launch calibration knowledge, to the ground support requirements or to the post-launch data processing;

c) to show by means of a Budget Table the value allocated to each error or accuracy component, and to explain how these values have been summed, and how the sum relates to the original system-level - usually IRD - requirement;

d) to explain any assumptions or caveats which have been considered in the allocation process, and/or any aspects of "engineering judgement" which apply;

e) to indicate the source document and paragraph number, and the destination document and paragraph number, for each flowed-down requirement.

NOTE: the phrase "pre-calibration performance" means the performance of the instrument as it is to be demonstrated prior to calibration in the UK (sometimes called "calibratability"). The term "instrument" generally means one or more instrument subsystems. However, for specification and verification purposes all such flowed-down requirements are considered to be instrument requirements.

1.2.3 Format

The SPRAT is arranged as follows. The header line of most SPRAT paragraphs is intended to be machine-readable so that requirements can easily be grouped, extracted, etc. with respect to any of the attributes shown. System-engineering notes intended to describe assumptions made, or to provide background information, are included in [square brackets] following the requirement paragraph to which they apply.

The attributes which are included in the first (header) line of each requirement paragraph are:

a) "hash" sign used to identify a header line

b) source/destination document codes and Budget name (where applicable)

Source codes used are as follows:

IRD	HIRDLS Instrument Requirements Document	(Ref. 1.4.2)
GIRD	General Interface Requirements Document	(Ref. 1.4.4)
UIID	HIRDLS Unique Instrument Interface Document	(Ref. 1.4.5)
SPEC	[NASA/EOS/CHEM] Specification for HIRDLS	(Ref. 1.4.3)

Destination codes used are as follows:

ITS	Instrument Technical Specification	(Ref. 1.4.1)
EID	External Interface Description	(Ref. 1.4.20)
PLCR	Pre-launch Calibration Requirements (doc.)	(Ref. 1.4.33)
FOCD	Flight Operations Concept Document	(Ref. 1.4.7)
ATBD	Algorithm Theoretical Basis Document for Level 0-1 processing	
GSE	Ground Support Equipment requirements documents	(Refs. 1.4.9, 1.4.12, 1.4.15)

c) System-level budget to which the requirement relates. The standard 8-character budget code is shown

The following table shows how the SPRAT relates to other HIRDLS top-level documents. The formal flow-down path is direct - not VIA the SPRAT. The SPRAT is not under full configuration control and, in cases of conflict, does not take precedence. However, such cases are not intentional and will be resolved when attention is drawn to them.

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   SCIENCE-DERIVED    SPACECRAFT      SPACECRAFT
     INSTRUMENT       INTERFACE      ACCOMMODATION   SPECIFICATION
    REQUIREMENTS     REQUIREMENTS     ALLOCATIONS     FOR HIRDLS
    [IRD - PIs]     [GIRD - NASA]    [UIID - NASA]   [SPEC - NASA]
          |                |               |
          |                |               |               |
          |________________|_______________|_______________|
                                 |
                                 |
                                 |
                                 |---------------------- SPRAT
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       ______________________________________________________________
       |               |               |             |             |
       |               |               |             |             |
       |               |               |             |             |
  INSTRUMENT        EXTERNAL       PRE-LAUNCH       GROUND       POINTING
  PERFORMANCE      (S/craft)       CALIBRAT'N      SUPPORT         DATA
  REQUIREMENTS     REQU'MENTS      REQU'MENTS     REQU'MENTS    PROCESSING
     [ITS]           [EID]           [PLCR]       [various]     REQU'MENTS
       |               |               |                         [part of
       |               |               |                       Level 0-1 ATBD]
       |               |               |
  PERFORMANCE      (to UIID,       PRE- LAUNCH
 VERIFICATION         IDD)         CALIBRATION
  PLAN [PVP]                       PLAN [PLCP]
```

1.4 APPLICABLE AND REFERENCE DOCUMENTS

The applicability of some of these is specified in section 1.5. In the case of HIRDLS documents, the latest revision is intended (unless otherwise indicated)

Group 1: source documents from which SPRAT requirements are derived

1.4.2	HIRDLS-SC-HIR-18	Instrument Requirements Document (IRD)
1.4.3	GSFC-422-36-02	Specification for HIRDLS
1.4.4	GSFC-422-11-12-01	General Interface Requirements Document (GIRD) for EOS common spacecraft/instruments
1.4.5	GSFC-422-36-05	Unique Instrument Interface Document for EOS/HIRDLS (UIID)

/continued . . . .

Group 2: destination documents into which SPRAT requirements flow

1.4.1	HIRDLS-SP-HIR-13	Instrument Technical Specification (ITS)
1.4.20	HIRDLS-SP-HIR-14	HIRDLS External Interface Description (EID)
1.4.33	HIRDLS-SP-HIR-164	Pre-launch Calibration Requirements (PLCR)
1.4.7	HIRDLS-OP-HIR-???	Flight Operations Concept Document (FOCD)
1.4.9	HIRDLS-SP-HIR-39	IEGSE requirements document
1.4.12	HIRDLS-SP-HIR-47	ITGSE requirements document
1.4.15	HIRDLS-SP-HIR-???	IMGSE requirements document
1.4.54	HIRDLS-SW-HIR-168	Algorithm Theoretical Basis Document (Level 0-1)

Group 3: explanatory and other documents referenced in the SPRAT

1.4.6	HIRDLS-SP-HIR-200	Internal Int/face Control Document (system section)
1.4.8	HIRDLS-OP-OXF-8B	Azimuth scan swath width and overlap
1.4.10	HIRDLS-SP-HIR-90	Fiducial atmospheric radiance profiles
1.4.11	HIRDLS-TC-HIR-53	Optical System Performance
1.4.13	HIRDLS-PA-HIR-6	Contamination Control Plan
1.4.14	HIRDLS-TC-HIR-32	Optical System Description Document
1.4.18	HIRDLS-TC-HIR-149	HIRDLS Acronyms, Abbreviations, Dictionary of Terms and Optical System Terminology
1.4.19	HIRDLS-SP-HIR-155	Spectral performance and spectral verification requirements for HIRDLS optical elements
1.4.21	HIRDLS-TC-HIR-69	Instrument spectral requirements
1.4.22	HIRDLS-SP-HIR-154	Out-of-band spectral blocking requirements
1.4.23	GSFC-424-28-12-01	HIRDLS/EOS-CHEM Instrument Description Document
1.4.25	HIRDLS-TC-OXF-76	Derivation of HIRDLS elevation scan range
1.4.26	HIRDLS-TC-OXF-51	Likely HIRDLS Scanner torques
1.4.27	HIRDLS-TC-OXF-53	HIRDLS scan pattern control
1.4.28	HIRDLS-TC-NCA-18	Signal processing of HIRDLS radiometric data
1.4.29	HIRDLS-TC-OXF-72	Signal channel dynamic range, gain settings and A-D conversion
1.4.32	HIRDLS-TC-NCA-05	Effect of demodulation method on SNR
1.4.34	HIRDLS-TC-OXF-90	Some detector specification and cryo system design issues
1.4.36	HIRDLS-TC-OXF-98	Jitter definitions and requirements
1.4.37	HIRDLS-TC-RDU-111	Spectral PASSBAND & BLOCKING Budget Descr. Document
1.4.39	HIRDLS-TC-RAL-55	IFOV Performance
1.4.40	HIRDLS-TC-RAL-43	Estimates of stray light from incoherent scatter
1.4.41	HIRDLS-TC-NCA-42	OPDETPRE Budget Description Document
1.4.42	HIRDLS-TC-OXF-97	RADMETAC Budget Description Document
1.4.43	HIRDLS-TC-RAL-66	APART analysis of incoherent scatter
1.4.44	HIRDLS-TC-OXF-118	RADCALAC Budget Description Document
1.4.45	HIRDLS-TC-RAL-46	Coating scatter measurements and analysis
1.4.46	HIRDLS-TC-RAL-47	Ghost analysis plan and results
1.4.47	HIRDLS-TC-RAL-48	Diffracted stray light and its rejection
1.4.48	HIRDLS-TC-RAL-49	Criteria for sizing of apertures
1.4.49	HIRDLS-TC-OXF-155	SPECKNOW Budget Description Document
1.4.50	HIRDLS-PM-OXF-153	Instrument Spectral Requirements Flowdown
1.4.51	HIRDLS-TC-OXF-151	HIRDLS attitude retrieval: an approximation
1.4.52	HIRDLS-TC-OXF-149	Description of HIRDLS attitude retrieval model
1.4.53	HIRDLS-TC-OXF-136	HIRDLS pointing re-visited
1.4.55	HIRDLS-TC-UCB-5	HIRDLS In-flight Signal Processing

1.5. ON THE APPLICABILITY OF SOME REFERENCE DOCUMENTS

> Ref. 1.4.3 (GSFC-422-36-02) Specification for HIRDLS: this NASA document specifies the contractual technical requirements for HIRDLS. Some requirements originate here and are not covered in any other NASA requirements documents. These requirements are included in the flow-down table (section 5) and are - where shown - addressed in the SPRAT.

> Ref. 1.4.11 (TC-HIR-53) Optical System Performance: this document will define the expected (system-level) performance of the optical system, updated from time to time as fresh analyses are completed. This will eventually become the document against which instrument performance test results are compared. It will include all aspects of optical system performance, i.e. image quality, IFOV, spectral response, out-of-field margins, etc. NOT YET RELEASED

> Ref. 1.4.14 (TC-HIR-32) Optical System Description Document: this describes the chosen optical system design

> Ref. 1.4.20 (SP-HIR-14) HIRDLS External Interface Description (EID): this HIRDLS document contains the instrument-S/C interface requirements and constraints, and is formatted such that it (approximately) maps on to the GIRD paragraphs which it addresses. It is the primary vehicle for conveying HIRDLS external interface information to NASA (UIID, IDD) and to the S/C Contractor (ICDs).

> Ref. 1.4.23 (Instrument Description Document): this NASA document reproduces most of what is in the EID (ref. 1.4.20) but in a slightly different format.

1.6 ABBREVIATIONS & ACRONYMS

All the abbreviations and acronyms used in the SPRAT are listed in document TC-HIR-149B: "HIRDLS Acronyms, Abbreviations, Dictionary of Terms and Optical System Termino
logy" (ref. 1.4.18)

SECTION 2

GENERAL REQUIREMENTS & DEFINITIONS

2.1 GENERAL REQUIREMENTS AND DEFINITIONS

2.1.3 The phrase [design aim] has been used in cases where:
a) the required value is indeterminate but a target value has been suggested, or
b) a limiting value has been specified, but a more favourable value is indicated if it can be achieved without becoming a 'design driver'

2.1.4 Deleted

2.1.5 The terms 'beginning of life' (BOL) and 'end of life' (EOL) refer to the lifetime of the flight instrument in orbit, and imply that some change in performance or operating range with lifetime is expected; a 5-year lifetime in orbit should be assumed

Where an allowance for degradation of a performance parameter has been made, both the BOL and EOL values are given. The term "degradation" is intended to apply over the working life of the instrument, i.e. between initial pre-launch characterisation and EOL

2.1.8 The term 'on demand' means either 'by ground command' or 'by stored sequence control'.

2.1.9 The terms 'measured' and 'sampled' shall be interpreted to mean 'sampled via telemetry'.

2.1.10 The terms 'subsystem' and 'sub-assembly' shall be interpreted according to the definitions given in Ref. 1.4.6.

2.1.11 In cases where a requirement implies that an interface be agreed between two subsystems, it shall be agreed between the individuals responsible for each subsystem and will be documented in Ref. 1.4.6

2.1.12 Unless specifically referred to, the wording of the SPRAT takes no account of any possible 'contingency' modes of operation, or duplication of any subsystems which may be included for reliability; in such cases the wording should be interpreted as appropriate.

2.2 ORBIT AND SPACECRAFT PARAMETERS

#2.2.1 IRD 2.1.2 EID

The HIRDLS instrument design assumes that the EOS CHEM S/C is in a (sun-synchronous) orbit. The beta angle value must not be less than 13 degrees

[The sun-synchronous orbit assures complete global coverage, including the polar regions. The minimum beta angle constraint relates to the need to keep direct sun out of the viewing aperture at all times]

#2.2.3 IRD 2.1.3 EID ATBD

Requirements for knowledge of instrument position and angular velocity in orbit are given in the IRD. However, these do not take into account the requirements relating to the co-ordinate frame conversions needed for the tracking of tangent point location to the accuracy corresponding to the LOS pointing knowledge requirements given elsewhere in the IRD.

When this is done (see ref. 1.4.51), the following position requirement is found to encompass all HIRDLS requirements, and is consistent with the expected knowledge data to be provided by NASA/GSFC Code 500 (Flight Dynamics Branch):

a) the error in the knowledge of the spacecraft relative distance from the center of the earth at any instant of time shall not exceed 10 m (3 sigma);

b) the error in the knowledge of the position of the spacecraft across-track and along-track at any instant of time shall not exceed 30 m (3 sigma);

#2.2.5 GIRD 9.1 ITS EID

The instrument design shall assume a nominal orbit mean altitude of 705 km (ref. 1.4.25), and shall allow for the following variations and tolerances (3 sigma):

+/- 0.25 deg for s/c attitude variation & offset

+/- 0.05 deg for instrument misalignment on s/c

+/- 15 km for orbit eccentricity

+/- 15 km for uncertainty in s/c altitude

+8/-13 km for earth oblateness

[The orbit altitude range of 700 to 737 km given in the GIRD (ref. 1.4.4) is assumed to include some of the above effects; however, additional margin needs to be included, which mainly affects the elevation scan range and the size of the main viewing aperture. See ref. 1.4.25 for derivation of the required elevation scan range]

#2.2.7 IRD 2.1.4 EID

The IRD requires the spacecraft to have roll and pitch axis rates which deviate from nominal by 1 arcsec/second or less. After discussion with NASA, these requirements have been amplified here; they are expected to be achieved and have been assumed in the allocation of budget figures:

i) pointing accuracy: within 0.25 deg (3-sigma value) of nominal alignment with each SRCF axis (offset plus variations) (see below for definition of SRCF)

ii) stability: +/- 180 arc seconds (3-sigma) variation about actual mean offset at all times

iii) rates: normally < 1 arc-sec per second [this will allow HIRDLS to collect useable science data even with failed HIRDLS Gyroscope Subsystem]

iv) jitter (rms amplitude for all frequencies above 10 Hz): [TBD]

2.3 INSTRUMENT ENVELOPE, CO-ORDINATES AND AXES

#2.3.1 ITS

Three Reference Coordinate Frames are defined as follows:-

> SRCF: the "Spacecraft" Reference Co-ordinate Frame is defined in IRD para. 1.5. It is relative to the centre of the Earth and the instantaneous orbit plane.

> IRCF: the Instrument Reference Co-ordinate Frame shall be fixed relative to the instrument-to-S/C mounting feet and IAC. Its axes shall be parallel to the corresponding SRCF axes within the tolerances given in the PLACEXTL Budget (section 4.11).

> TRCF: the Telescope Reference Co-ordinate Frame shall be fixed relative to the Telescope. Its axes shall be parallel to the corresponding IRCF axes within the tolerances given in the PLACINTL Budget (section 4.12).

2.4 OPTICAL REQUIREMENTS

#2.4.1 ITS PLCR GSE

Terms used in section 2.4 (and elsewhere) in the SPRAT are defined as follows, and the same definitions shall, where applicable, apply in at least the following HIRDLS documents:

- Instrument Technical Specification (Ref. 1.4.1)
- External Interface Description (Ref. 1.4.20)
- Pre-launch Calibration Requirements doc. (Ref. 1.4.33)
- All Ground Support Equipment requirements documents

> POA - the 'projected optical axis' is the projection of the system optical axis, equivalent to the ray from the centre of the detector array (point X in Fig 4-1) which passes through the centre of the system aperture stop, and is projected via the telescope on to the scan mirror

> ILOS - the 'instantaneous line of sight' is the direction of the POA after reflection from the scan mirror

> CHILOS - the 'channel instantaneous line of sight' is the direction of the ray from the centre of any given channel field stop which passes through the centre of the system aperture stop, and is projected towards the atmosphere via the telescope and the scan mirror

[each of the 20 off-axis CHILOSes (!) has a different time-dependent LOS angle due to azimuth scan angle-dependent rotation of the composite field image in the atmosphere. This effect is accurately calcula ble and may not be of relevance in the engineering design of the instrument itself. CHILOS needs to be defined as it affects ground data processing and other non-instrument considerations, and may be needed in order unambiguously to define some instrument pointing requirements]

> BORESIGHT - the instrument boresight is the direction of the ILOS when the scan mirror is in its 'scan datum' position (see section 3.4)

> BORESIGHT PLACEMENT - the mean alignment of the instrument boresight with respect to the SRCF

> ILOS JITTER - this term is used to describe variations with time in the relative pointing knowledge of the ILOS for frequencies above the measurement bandwidth of the Gyro Subsystem, i.e. the ILOS JITTER limits are based on the assumption that its amplitude is unknown. See ref. 1.4.36

[ILOS JITTER relates to higher frequency disturbances emanating from non-ideal scan mirror motions, vibration imparted by the coolers, external disturbances from the spacecraft or other instruments, etc. A crucial design objective is that the Optical Bench should be made sufficiently stiff that the gyro may be considered to be rigidly connected to all the optical components which determine the overall ILOS (excluding wanted scanner motions) at all frequencies corresponding to periods longer than about 25 mS]

> In references to the OB, the phrase 'associated optical components' shall be taken to include all mirrors, the chopper, the scanner, the detector housing and the lens assembly

#2.4.11 IRD 2.6.1 ITS OPDETPRE

The requirements given in IRD (ref. 1.4.2), para 2.6.1 apply to the vertical IFOV response of each channel, assuming a uniform scene brightness and with respect to a 'datum line' in the atmosphere. For the purpose of this requirement the 'datum line' is defined as the horizontal line in the atmosphere, perpendicular to the instrument ILOS, which passes mid-way between the 50% relative amplitude response lines

The vertical IFOV width/shape error budgets shall include all those parameters which can influence the overall vertical IFOV requirement. The IRD requirement is expressed in terms of the in-orbit field projected into the atmosphere. It directly translates into an angular field response at the entrance pupil of the telescope, based on producing an image of the field stop of each channel that has a nominal vertical dimension in the atmosphere of 1 km at a distance of 3000 km, thus:-

> The end-to-end angular response of each spectral channel to a line source perpendicular to the ILOS, parallel to the IRCF XY plane, and moving parallel to the IRCF Z axis shall be a function with a full width at half maximum (FWHM) of 333 +17/-33 microradians.

This value has been assumed in the definition of the IFOV solid angle factor in the OPDETPRE (throughput) Budget.

[the wording of the IRD requirement is intended to ensure that the 'wings' of the field in the vertical direction are as 'tight' as can reasonably be achieved]

#2.4.13 IRD 2.6.1 ITS OPDETPRE
In the horizontal direction the IFOV in the atmosphere for each channel shall be as constrained by NEN, optics and detector design considerations, but shall not exceed 72 km in length. A nominal value of 10 km is recommended provided it meets the relevant requirements.

The IRD requirement is expressed in terms of the in-orbit field projected into the atmosphere. It directly translates into an angular field response at the entrance pupil of the telescope, based on producing an image of the field stop of each channel that has a nominal horizontal dimension in the atmosphere of 10 km at a distance of 3000 km, thus:-

> In the horizontal direction, the angular IFOV in the atmosphere at the tangent point, for each channel, shall not exceed 72 km 24 milliradians. A horizontal IFOV of 10 km 3.33 milliradians between the 50% relative response points is recommended provided that this is consistent with meeting all radiometric requirements.

This value has been assumed in the definition of the IFOV solid angle factor in the OPDETPRE (throughput) Budget.

#2.4.15 IRD 2.6.2 OUTFIELD
The optical system shall be designed to minimise adverse effects of:

i) diffraction at any physical aperture, particularly on the fore-optics side of the chopper

ii) scatter of energy into the instrument IFOV, particularly on the fore-optics side of the chopper

iii) multiple reflections which could result in any detector receiving chopped energy from outside its wanted IFOV

iv) Specifically, in any channel the total out-of-field signal shall not exceed 0.4% of the signal or 100% of the specified NEN when viewing either a black target at 290K or the atmosphere, based on the radiance profiles given in ref. 1.4.10

For the purposes of this requirement the boundaries between the "in-field" and "out-of-field" regions of each channel shall be assumed to be the upper and lower limits in the atmosphere of the IFOV which lie at +/- 4 km relative to the horizontally-averaged centroid

The above requirements may not be directly verifiable by test at instrument level. They need to be factored into the design of the optical system with regard to suppression of near-field diffraction, incoherent scattered stray light and "ghosting". It must be shown by analysis that there is adequate margin in the design with respect to each of the above artifacts, and some limited sensitivity testing should be attempted if practicable.

In the case of item (ii) above, the OUTFIELD Budget allocation in respect of incoherent scatter can be tied to a maximum EOL particulate contamination at MIL-STD-1246 Level 400 as reported in refs. 1.4.40 and 1.4.43. See also CONTAMIN Budget, section 4.2.

[These requirements relate to the unwanted out-of-field energy (OUTFIELD) Budget. Modulated (chopped) stray signal is particularly undesirable, as it varies with the position of the scan mirror. Such effects could easily prevent the stringent radiometric calibration accuracy requirements from being satisfied]

#2.4.16 IRD 2.6.2 ITS OUTFIELD
The design of the optical system shall be such that multiple reflections do not contribute to the total out-of-field signal in any channel more than the amount allocated for this item in the OUTFIELD Budget

#2.4.17 IRD 2.6.2 ITS OUTFIELD
The design of the optical system shall be such that diffraction from out-of-field sources does not contribute to the total out-of-field signal in any channel more than the amount allocated for this item in the OUTFIELD Budget

#2.4.18 IRD 2.6.2 ITS OUTFIELD CONTAMIN
The design of the optical system shall be such that incoherent optical scattering does not contribute to the total out-of-field signal in any channel more than the amount allocated for this item in the OUTFIELD Budget

#2.4.20 IRD 2.6.3 IFOVKNOW
[RRP = relative response point(s)]
The relative angular position at which the the horizontally integrated IFOV response of each channel is measured must be known with an accuracy of 2 arcseconds. For positions between the 1% RRP the error in the knowledge of the relative amplitude response must not exceed 1%.

The spatial resolution for this knowledge must be at most 7 arcseconds with three samples per resolution element. Between either 1% RRP and the adjacent 0.2% RRP the error in the knowledge of the relative amplitude response must not exceed 100%. Compliance with these requirements is required by both measurement and analysis, and shall be maintained over the operational lifetime of the instrument in orbit.

#2.4.21 IRD 2.6.3 PLCR IFOVKNOW
For each channel, prior to launch, the VIFOV angular response at the instrument entrance pupil shall be characterised both by analysis and by measurement, having assumed or made (respectively) any anticipated adjustments, with the following accuracy and resolution

[RRP = relative response point(s)] :-

> Within the 1% RRP: in amplitude, to within +/- 0.5% of the peak response and with an angular resolution of 4 arc seconds or the diffraction-limited spot size (whichever is larger); in angle, to within +/- 1 arc second relative to the instrument boresight. The scan rate for this measurement shall not exceed 40 arc sec per second

> In the 'wings' between the 1% and 0.2% RRP: to within a factor 2 of the measured amplitude, with an angular resolution of one quarter of the vertical IFOV or better

> Over the whole angular range of the overall instrument field beyond the 0.2% RRP: with sufficient sensitivity to verify the requirement specified in 2.4.15 (iv)

The horizontal IFOV of each channel shall be similarly characterised but in this dimension the required accuracy and resolution may be relaxed by a factor 5 relative to the value stated above

[Each IFOV must be carefully characterised (i.e. mapped) to determine the precise shape of the angular response function with the instrument held within the nominal operating temperature range. Half the desired maximum in-orbit uncertainty in this parameter has been allocated to measurement error, and half to subsequent changes over time

#2.4.23 IRD 2.6.3 ITS IFOVKNOW
This flows into the ITS as a long-term stability requirement (BOL to EOL). The IFOV profile of each channel between the 0.2% relative response points shall be such that the response averaged over any interval equal to one tenth of the IFOV in the vertical and horizontal spatial dimensions respectively shall not change by more than that allowed in the IFOVKNOW budget for possible change in VIFOV after characterisation.

[The change of IFOV profile with time (if any) after launch cannot be measured. However, it is important that it be shown by analysis that the IFOV of each channel is not likely to change after final characterisation by more than the permitted amount. The latter, combined with the uncertainty in characterisation, gives an estimate of the overall uncertainty in the knowledge of the IFOV profiles in orbit]

#2.4.25 IRD 2.6.3 ITS IFOVKNOW
For each channel relative to the centre channel of the array, the relative altitude angle between the centroids of the two channels shall not change by more than +/- 1 arcsecond during the operational lifetime of the instrument in orbit.

2.5 SPECTRAL REQUIREMENTS

#2.5.1 IRD 2.4.1 PASSBAND

i) The end-to-end spectral passband profile of each channel shall be as specified in ref. 1.4.2.

ii) The spectral passband for each channel shall be primarily determined by a multi-layer coated bandpass filter operating at nominally the same temperature as the Optical Bench

iii) The end-to-end profile will, in principle, be different from the passband profile of the filter itself, due to the effect of the anti-reflection coatings on the lenses and detector elements, the intrinsic spectral response characteristic of each detector element and of any other spectrally non-uniform components in the optical path.

The PASSBAND Budget is described in ref. 1.4.37. The formal flow-down path for the IRD spectral requirements is via ref. 1.4.21 and 1.4.19, both documents being adjunct to - and referenced in - the ITS.

#2.5.5 IRD 2.4.3 IRD 2.4.4 BLOCKING

For each channel, outside the 0.2% relative response points (RRP), the total spectrally-integrated transmission:

i) shall not exceed 1% of the total spectrally-integrated transmission between the 0.2% points when viewing a black body at 300K, and

ii) shall not exceed 1% of the total spectrally-integrated transmission between the 0.2% points, or 50% of the NEN specified in ref. 1.4.2 (whichever is greater) when viewing the atmosphere over the specified atmospheric sounding range

Atmospheric and black body data relating to this requirement will be found in ref. 1.4.22, which is adjunct to the IRD

The BLOCKING Budget is described in ref. 1.4.37. The formal flow-down path for the IRD spectral requirements is via ref. 1.4.21 and 1.4.19, both documents being adjunct to - and referenced in - the ITS.

To avoid undue complication the requirements of IRD 2.4.3 and 2.4.4 - which are neither mutually exclusive nor mutually consistent - have been amalgamated. The knowledge requirements of IRD 2.4.4 will be met provided that the requirements given in this SPRAT para. are met and it is assumed that the out-of-band response is zero.

The out-of-band blocking requirement given above is not sufficient. For the atmospheric sounding views there is a large variation in source 'brightness' with both tangent height and spectral frequency; also different channels have different sensitivities in this respect. Thus, in addition to the above requirement, and derived from it, the maximum desired transmission of each channel outside the passband is given as a function of spectral frequency in ref 1.4.22

#2.5.6 IRD 2.4.2 SPECKNOW

[RRP = relative response point(s)]

> The frequency at which the relative spectral response of each channel is measured shall be known with a 3-sigma accuracy of 0.6 w/n. For frequencies between the 1% RRP the error in the knowledge of the relative amplitude response to unpolarized radiation shall not exceed

+/- 1%, with a spectral resolution not exceeding 1 w/n, and with three samples per resolution element.

> Between either 1% RRP and the adjacent 0.2% RRP the error in the knowledge of the relative spectral response must not be greater than 100%. Compliance with these requirements shall be demonstrated by both measurement and analysis, the requirements being met during the operational lifetime of the instrument in orbit.

#2.5.7 IRD 2.4.2 PLCR SPECKNOW
The overall spectral profile of each pass band shall be characterised by measurement and by analysis prior to launch, to the following accuracy and resolution:-

> Between the 1% (RRP): to within +/- 0.5% of the peak response, with a spectral resolution of 1 wavenumber or better, an absolute spectral accuracy of 0.6 wavenumbers (3-sigma) or better, and an adequate relative spectral accuracy across each passband (note 1, section 4.7). For this measurement the scan rate shall not exceed 15 wavenumbers per second of time

> Between the 0.2% RRP but ouside the 1% RRP: to within a factor 2 of the measured amplitude, with a spectral resolution of two wavenumbers or better, and an absolute spectral accuracy of one wavenumber or better

> Over the spectral range 1 to [TBD] micron, but outside the 0.2% RRP: with sufficient sensitivity to detect an out-of-band spectral 'leak' having an amplitude greater than 0.1% of the peak in-band response, with a spectral resolution of 5% or better, and with an absolute spectral accuracy of the larger of 10 wavenumbers or 1%

> The above measurements shall if necessary be performed at more than one warm filter temperature and/or detector-cold-filter temperature. The number of measurements required shall be determined by analysis of the temperature coefficients and variations affecting this parameter

> The beam used to illuminate the instrument entrance pupil during these measurements shall be uniform in intensity to within +/- 10% or better

[It is not sufficient that the spectral passband for each channel be within the specified (relatively coarse) limits. Each spectral response profile must be carefully measured with the instrument held within the nominal operating temperature range and at more than one detector/filter temperature. Half the desired maximum in-orbit uncertainty in this parameter has been allocated to measurement error, and half to subsequent changes over time - see footnote to next para]

#2.5.9 IRD 2.4.2 ITS SPECKNOW
The long-term stability requirements relating to the overall spectral response profile of each channel after characterisation imply that the instrument be designed so that following limits are not exceeded:-

a) between the 1% relative response points (RRP):-

> Permanent spectral frequency shift in passband edges: 0.1 w/n

> Permanent changes in passband profile amplitude: 0.5 %

> Temperature-induced frequency shift in passband edges during lifetime: 0.16 w/n

> Temperature-induced variation in bandpass profile amplitude during lifetime: 0.2 %

These stability requirements shall be met over at least the stated temperature intervals, applied simultaneously, about any temperature in following ranges:

> Detectors and Cold Filters: any +/- 0.5 K interval; 60 to 80 K

> Warm Filters and other optical components mounted on the Optical Bench: any +/- 2.5 K interval; 290.5 to 300.5 K

[The change of spectral profile with time (if any) after launch cannot be measured. However, it is important that it be shown by analysis, etc. that the passband of each channel is not likely to change after final characterisation by more than the permitted amount. The latter, combined with the uncertainty in the final characterisation, gives an estimate of the overall uncertainty in the knowledge of the passband profiles in orbit]

2.6 RADIOMETRIC REQUIREMENTS

#2.6.1 The term 'chopped beam' refers to:

a) the envelope of the ray bundle on the "atmosphere" side of the chopper, i.e. between the chopper and the primary paraboloid mirror, between the latter and the scan mirror and reflected from the scan mirror towards the atmosphere, and

b) the envelope of the ray bundle reflected from the chopper, i.e. between the chopper and the space-reference view relay mirror, and reflected from the relay mirror through the reference view port

The 'net size' of the chopped beam at any given location refers to the geometric projection of the beam formed by the entrance pupil and the instrument CIFOV, including aberrations but excluding diffraction wings

The term 'oversize beam' refers to the geometric projection of the beam (towards the atmosphere or the IFC mirror) formed by the (oversize) Primary Field Mask and the (oversize) Primary Diffraction Baffle, or to the pro-rata equivalent oversize chopper space-reference view beam

[It should be noted that the chopped beam will not have a perfectly circular normal cross section, so that the diameter will vary slightly for different rotational orientations within the beam.

The definition is needed because it will be important properly to calculate the 'clearance' around the beam with a view to minimising it in certain critical places, e.g. where the beam passes through the main viewing aperture or passes the edge of the moveable sunshield]

#2.6.3 ITS

There shall be no significant vignetting of the 'oversize chopped beam' at any surface or aperture

#2.6.5 IRD 2.5.2 ITS

The IFC space views shall be via the same optical train (including the scan mirror) as is used for normal atmospheric scanning, and shall (for each detector channel) be at or above the minimum tangent-point height shown in ref. 1.4.2

#2.6.6 IRD 2.5.1 RADMETAC

The maximum error in radiometric measurement of atmospheric emission in all channels over the operational elevation scan range at EOL shall not exceed the root-square sum of:-

For channels 2 through 5:	0.5% of the atmospheric radiance and 50% of the maximum radiometric noise specified for that channel in the IRD (ref. 1.4.2)
For all other channels:	1% of the atmospheric radiance and the maximum radiometric noise specified for that channel in the IRD (ref. 1.4.2)

#2.6.7 IRD 2.5.1 PLCR RADMETAC
The end-to-end linearity of the 21 signal channels shall be determined during pre-launch calibration of the instrument, such that the gain of each channel be known over the whole range of radiance input levels from zero nominal scene radiance to 1.25 times the nominal full-scale scene radiance, with a relative accuracy of +/- 0.1%

[This requirement relates to item #13 of the RADMETAC Budget. See also para 2.9.19 and 2.9.21]

#2.6.19 IRD 2.5.1 ITS RADMETAC
The mean surface temperature of the scan mirror, averaged over the chopped beam, shall not vary within one elevation scan, and between atmospheric and IFC black body views, as a result of the non-uniform temperature distribution, by more than the allowances in the RADMETAC Budget (Section 4.10, item #7)

The above implies maximum temperature gradients across the scan mirror in the vertical and horizontal directions respectively.

#2.6.20 IRD 2.5.1 ITS RADMETAC
Knowledge of the temperature of the scan mirror front surface at several locations is required to an absolute accuracy of +/- 2 deg. or better, and a location-to-location differential accuracy of +/- 0.25 deg. or better, or as shown in the RADMETAC budget if more stringent.

A minimum of 5 sensors shall be attached to the rear surface of the mirror, positioned approximately behind the optical centroid and behind the +Z, -Z, +Y and -Y edges of the area 'illuminated' by the incident beam when the scan mirror is in its 'datum' position.

[This knowledge requirement is to allow corrections to be made in order not to exceed the error allocation to item #8 of RADMETAC]

#2.6.21 IRD 2.5.1 ITS RADMETAC
The effective emissivity (as defined in TC-OXF-97) of the IFC black body shall not, prior to EOL, differ from that of a perfect, (unit emissivity) black body by more than the allowance given in the RADMETAC budget.

[This requirement relates to item #3 of the RADMETAC Budget]

#2.6.23 IRD 2.5.1 PLCR RADMETAC RADCALAC
The IFC black body view signal for each channel shall be characterised prior to launch, by a combination of absolute thermometry and comparison with an external black body, with a brightness temperature error of less than the allowance in the RADMETAC budget, to include thermometric calibration and stability to EOL, comparison at instrument level with external targets, intrinsic thermal uniformity and offset between thermometers and radiating surface.

[This requirement relates to item #0 of the RADMETAC Budget]

#2.6.29 ITS FOCD

The temperature of both the IFC black body and the IFC paraboloid mirror shall be individually controllable on demand between the minimum natural temperature or 10C (whichever is higher) and 45C

[so that dependencies of measured calibration signal on IFC mirror temperature can be assessed in orbit]

#2.6.31 ITS

The moveable sunshield shall, at all orbit positions, remain open to the fullest extent while reliably preventing direct solar illumination of the interior of the instrument. Correct shadowing of the instrument viewing aperture is required to be continuously verified in operation by the use of sun sensors (see para 3.3.17)

The sunshield is required to move through an angle A in a maximum time T given by:

$$T = (A/2 + 1)$$

where T is in seconds and A in degrees.

The sunshield drive system shall be capable of moving the sunshield door angle in steps of 0.25 degrees or less.

#2.6.33 ITS

An angle sensor (e.g. potentiometer) shall be fitted to the moveable sunshield such that the angular position of the sunshield can be directly monitored independently of the sun sensors. Sunshield angle relative to the fully-closed position (including any conversion from e.g. volts to counts) shall be resolved to within +/- 0.25 deg, with an absolute accuracy over 5 years in orbit of +/- 2 deg or better

#2.6.35 ITS RADMETAC

The maximum degree of variation in the polarization-averaged specular reflectivity of the scan mirror (averaged over the illuminated portion of the surface, and for any field angle within the nominal FOV) with scan mirror position, at EOL, due to:-

(i) the intrinsic variation of the reflectivity of the clean surface with angle of incidence;

(ii) the scan-dependent variation of any change in reflectivity due to contamination

(iii) the movement of the illuminated portion of the scan mirror with mirror position, crossed with inhomogeneity of either intrinsic reflectivity or contamination

shall be such that the variation in chopped signal in any channel, when observing a cold target:

(a) shall not exceed four times the NEN specified for that channel in ref. 1.4.2 over the entire range of elevation scan angle, and

(b) shall not exceed eight times the NEN specified for that channel in ref. 1.4.2 over any five degree portion of the azimuth scan range.

[This requirement relates to items #8 and 10 of the RADMETAC Budget. See also the comments following the next para.]

#2.6.36 ITS RADMETAC

The total integrated scatter from the scan mirror surface, at EOL, for all angles of incidence relevant to the nominal FOV at all scan mirror positions, and all scattered angles greater than 0.5 degree from specular, shall not exceed [TBD] for all wavelengths between 6.5 and 18 microns

[This requirement relates to items #9 and 11 of the RADMETAC Budget. Elevation scan-angle dependent 'strays' are virtually impossible to characterise or 'calibrate out' satisfactorily after launch, and are particularly troublesome as, in principle, they impose a false component of spatial structure on to the atmospheric data. It is important that they be kept to a negligible level. These requirements anticipate that the stray will be measured, and removed with 80% accuracy.
It is expected that these requirements will drive the instrument contamination plan. The reflectivity requirement is intended to represent a level of variation about a factor of two greater than the clean surface variation for gold, to give some margin for contamination.
The scattering requirement is probably easily attainable for a clean surface (although not so easily measured because 0.5 degrees from specular is non-trivial) so that again this is intended to set limits to permissible pre-launch and in-flight contamination. Thus an actual measurement of the clean-surface scattering is permitted to use extrapolation to demonstrate that the scattering is much less than this requirement, at some infra-red wavelength. At the longer wavelengths this requirement is coupled with the surface form requirements.]

#2.6.38 ITS INSTRNEN
The rms noise induced on to an otherwise steady signal in each channel by the chopper, due to chopper imperfections, and - in turn - the maximum tolerable chopper irregularity, shall not exceed the value given in the INSTRNEN Budget (TSS allocation)

[In principle, chopper irregularities in amplitude or phase, from cycle to cycle, can modulate an otherwise perfectly steady signal. Such chopper-induced noise is assumed to be signal-amplitude-dependent and an allowance is made for this in the INSTRNEN allocation to the TSS. The allocation is proportional to the maximum expected atmospheric SNR, which in turn leads to a maximum tolerable chopper irregularity]

2.7 ALIGNMENT AND POINTING REQUIREMENTS

#2.7.3 ITS PLCR GSE
A pair of cube-corner retro-reflectors shall be attached to the OB in accordance with the requirements of ref. 1.4.31 [future rev.]

[These will be used in the Calibration Vacuum Facility at Oxford to monitor changes of alignment relative to the Collimator-Monochromator Subsystem during ILOS/FOV mapping]

#2.7.9 GIRD 3.5.2 ITS
An optical cube, known as the '(instrument) interface alignment cube' (IAC), shall meet the requirements given in ref. 1.4.4 [GIRD] para 3.5.2 ("Interface Alignment Cube") and shall be permanently attached to the instrument baseplate structure such that its faces are parallel to the instrument mechanical axes (Instrument Reference Co-ordinate Frame) to within 0.05 degree (180 arc seconds)

#2.7.12 PLACEXTL
In orbit, the instrument boresight must be directed to the atmospheric limb within acceptable angular tolerances. If these limits are not observed, the available scan range will not match the required angular range for the ILOS relative to the SRCF.

Accordingly, the total alignment errors between the instrument BORESIGHT and the SRCF are specified in the "requirement" line of the PLACEXTL Budget, which allocates these totals to EXTERNAL and INTERNAL alignment errors.

#2.7.13 EID PLACEXTL PLACINTL
During the process of integration of the HIRDLS instrument to the S/C, errors in PLACEMENT of the instrument IAC with respect to the SMRC shall not exceed the values shown in the "EXTERNAL - alignment of IRCF to SRCF" line of the PLACEXTL Budget.

The errors in the alignment of the instrument BORESIGHT with respect to the IRCF shall not exceed the values shown in the "INTERNAL" line of the PLACEXTL Budget, and the "requirement" line of the PLACINTL Budget.

#2.7.14 ITS PLACINTL
The errors in the alignment of the instrument BORESIGHT with respect to the TRCF shall not exceed the values shown for this in the PLACINTL Budget.

#2.7.15 ITS PLACINTL
The errors in the alignment of the Scanner azimuth axis with respect to the TRCF shall not exceed the values shown for this in the PLACINTL Budget.

The azimuth scan axis shall be fixed with respect to the TRCF and shall pass within 1 mm of the point of intersection of the POA and the scan mirror surface

#2.7.16 ITS PLACINTL

The errors in the alignment of the TRCF with respect to the IRCF shall not exceed the values shown for this in the PLACINTL Budget.

NOTE: the following paras 2.7.17 and 2.7.19 address the IRD pointing knowledge requirements for elevation and azimuth respectively, and how these relate to the POINTELV and POINTAZM Budgets. Paras. 2.7.21 thro' 2.7.29 deal with the flow-down of the various allocated line-items in these two Budgets.

REMAINDER OF THIS SECTION WITHDRAWN PENDING FURTHER REVISION

REVISED INSERT WILL BE MADE AVAILABLE AS SOON AS POSSIBLE

2.8 SCANNING AND OB-MOTION SENSING REQUIREMENTS

#2.8.3 Terms used in this section and not defined above, are defined as follows:-

> SCAN DATUM - this describes the position of the scan mirror for which both the mirror elevation and mirror azimuth scan angles are defined as zero, i.e. the scan mirror is parallel to the instrument YZ plane

> The term 'SCAN CYCLE' refers to an approximately 1-minute sequence consisting of one azimuth cycle with one or more elevation cycles and IFC views

> The POSITIVE direction of ELEVATION SCAN corresponds to CLOCKWISE rotation of the mirror from its scan datum position, viewed along the elevation axis in the general +Y direction, i.e. the ILOS moves LOWER in the atmosphere when viewing in the general -X direction (Fig. 2-1) as the ILOS angle becomes INCREASINGLY POSITIVE. When the scan mirror is in its datum position, the ILOS elevation angle is as given in 4.4.6.

> The POSITIVE direction of AZIMUTH scan corresponds to clockwise rotation of the mirror from its scan datum position, viewed along the azimuth axis in the general +Z direction, i.e. to the RIGHT when looking TOWARDS the nadir (Fig. 2-1)

> The term 'azimuth scan angle' refers to the angle of rotation about the (fixed) azimuth scan axis, independently of elevation scan angle. Each reference to it is specified either in terms of mirror rotation or ILOS rotation

> The term 'elevation scan angle' refers to the angle of rotation about the (moveable) elevation scan axis, independently of azimuth scan angle. Each reference to it is specified either in terms of mirror (mechanical) rotation or ILOS rotation

> TANGENT HEIGHT - this describes the shortest distance, measured towards the centre of the earth, between the instrument ILOS and the surface of the earth

#2.8.13 ITS
The elevation scan axis shall rotate with the azimuth scan motion and shall be:

i) orthogonal to within +/- 0.05 degree to the azimuth scan axis;

ii) parallel to within +/- 0.025 degree to the scan mirror surface;

iii) not more than 10 mm from the plane of the scan mirror surface

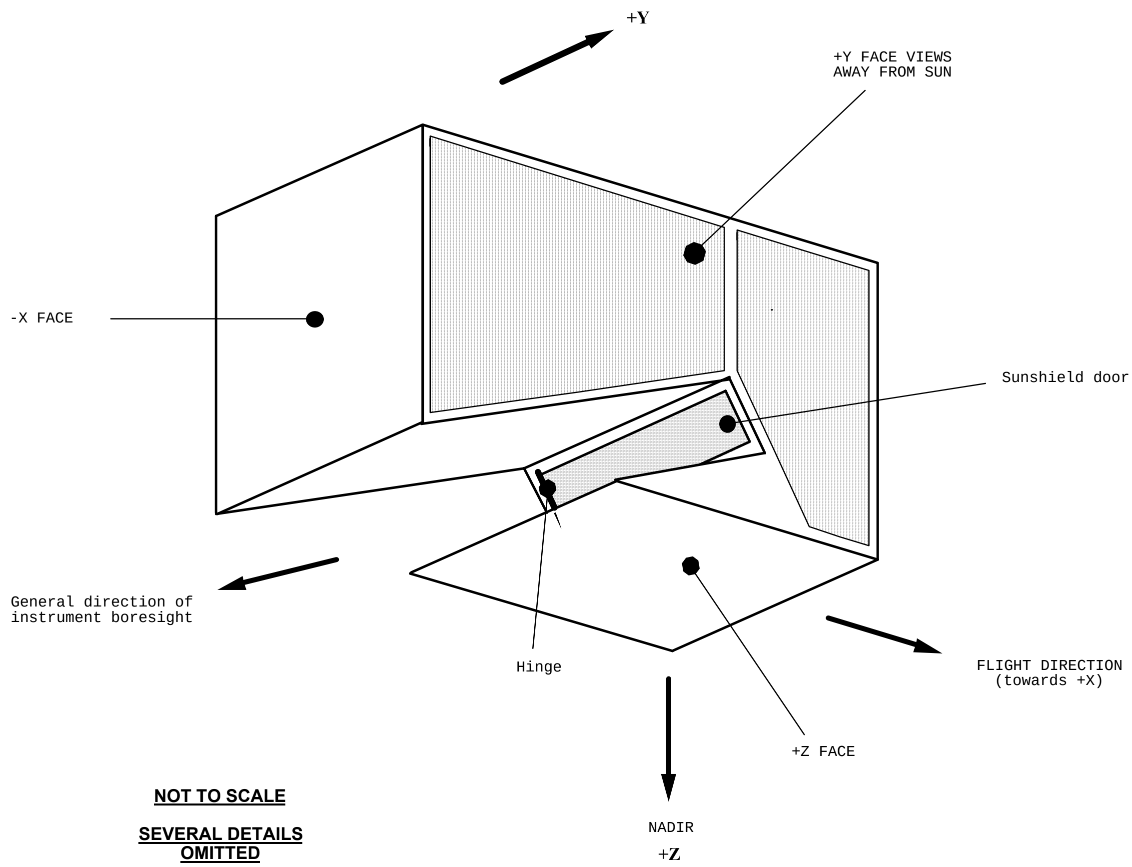

Fig 2-1 **OVERALL INSTRUMENT ENVELOPE AND AXES**

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#2.8.17 From: IRD 2.7.1 To: ITS 4.4.10.1
The total required elevation ILOS scan range computed as indicated in ref. 1.4.25 is:

Tangent Height increasing: 25.3 - 3.22 = 22.08 degrees
Tangent Height decreasing: 25.3 + 2.03 = 27.33 degrees

The minimum total elevation MECHANICAL scan range capability for the Scanner, computed as indicated in ref. 1.4.25, shall be:

"Tangent Height" increasing: 2.27 degrees
"Tangent Height" decreasing: 1.62 degrees

[To allow for misalignment, possible minor adjustments to the scan range, the scaling effect of azimuth scanning, etc., an 'engineering' margin of 0.5 (mechanical) degree HAS BEEN ADDED. The corresponding "ILOS" range is NOT required, i.e. the vertical extent and positioning of the viewing aperture in the outer structure, etc., is based on the required ILOS range, plus appropriate tolerances and margins to avoid vignetting]

#2.8.18 ITS PLCR
The ILOS elevation viewing angle shall be capable of being set on demand to a fixed value:-
a) absolutely to within 0.025 deg (90 arc sec) of any given angle within the available range, relative to the TRCF, and
b) with a resolution of 2 arc sec, and
c) to within 4 arc sec relative to any other stationary setting within the previous 60 minutes of time and assuming that all relevant temperatures are stable to 1C or better.

[the above performance is required for beam placement and stability during pre-launch characterisation and calibration of spectral and IFOV profiles]

#2.8.19 IRD 2.7.2 ITS PLCR FOCD
The ILOS elevation scan rate shall be programmable, with the capability of executing up to four constant-rate segments, of different rates, within a single elevation scan. The rate of each constant-rate segment shall be programmable over the range 0.01 to 1.0 deg/sec, with a resolution of 0.01 deg/sec or 10% of the rate, which ever is greater. After a rate transition, the scanner shall settle to within 10% of the new commanded rate within 0.1 second.

During any nominally constant-rate segment, scan rate variations (including jitter), smoothed by a PLPF with a nominal 'knee' frequency of 36 Hz, shall not exceed +/- 0.075 deg/sec.

[The IRD requires the slowest ILOS elevation scan rate to be 0.1 deg per second, based on viewing the atmosphere in orbit. However, in order to perform IFOV mapping during pre-launch calibration, a slower scan rate is needed]

#2.8.21 IRD 2.8.2 ITS

With respect to the scanner and internal instrument cavity design, the available ILOS azimuth scan range viewing the atmosphere (assuming the sunshield to be fully open) shall be between +21 degrees (i.e. 21 deg to the sun side) and -43 degrees (i.e. 43 deg to the anti-sun side)(see ref. 1.4.8), these angles being relative to the X-Z plane of the TRCF

#2.8.25 IRD 2.8.1 ITS

For elevation scans and IFC views, the ILOS azimuth viewing angle shall be capable of being set on demand, with a resolution of 0.01 degree (36 arc sec), and to within 0.02 deg (72 arc sec) of any given angle within the available range, relative to the TRCF

The ILOS azimuth scan rate shall be capable of being set on demand to any value between zero and 10 degrees/sec, with 8 bit resolution or better, and combined tolerance and maximum variation of +/- 10% of the demanded rate following any period of acceleration or deceleration. This is required for IFC space views, for slewing between elevation scans/IFC views and for pre-launch calibration of the horizontal IFOV.

The azimuth ILOS angle shall be commandable over the central +/- 5 deg portion of the azimuth scan range with a resolution of 10 arcsec.

The above angles and rate demands shall be set by ground command or stored sequence control. See refs. 1.4.26 and 1.4.27 for discussion of control requirements, scan rates, etc, but note that, in the event of conflict, the figures given in this SPRAT take precedence over those in the reference documents.

Over the whole azimuth scan range the resolution in the knowledge of the relative ILOS pointing direction shall be +/- 5 arcsec or less. The systematic error in the knowledge of the relative ILOS azimuth pointing direction shall not exceed +/- 5 arcsec over the central +/- 5 deg portion of the range.

[Normally, during the atmospheric sounding portion of an elevation scan, the scan mirror must be held in a stationary azimuth setting. Azimuth movement is permissible during the space-view calibration portion of the elevation scan]

#2.8.27 ITS

The scan mirror elevation and azimuth angles shall be transmitted to the telemetry stream at the same sample rate as each signal channel.

#2.8.31 IRD 2.10.4 ITS

The data from the Gyro channels shall be transmitted to the telemetry stream at the same sample rate as each signal data channel, each sample having a timing with respect to any signal channel data sample which is known to +/- 0.2 msec.

Each channel shall have a full-scale rate capability of at least 500 arc-seconds per second.

2.9 SIGNAL PROCESSING REQUIREMENTS

[It was necessary to define at an early stage a basic design concept for the HIRDLS signal processing. Spatial resolution, sampling rate and scan rate considerations led to the decision in principle to use a chopper to modulate and chop the optical beam, and to sample the signal synchronously with the chopper motion. A maximum total instrument data rate of 50 Kbits/sec has been agreed with NASA. It was also decided to average and filter the science-related (radiance, gyro and scan angle transducer) data by means of a programmable, digital (FIR) filter. These considerations were further developed and led to the requirements given in the following SPRAT paras]

#2.9.1 Terms used in this section are defined as follows:-

> 'Overall gain' is defined as the change of signal channel single-sample output count for a given change in the detector input (chopped) radiance averaged over a signal sample interval, the intervening signal processing channel being assumed linear over the specified working dynamic range

> 'Crosstalk' is defined as the fraction of the output count from a 'donor' signal channel which appears at the output of another ('receptor') signal channel due to unwanted coupling effects, but excluding the effect of out-of-field response

> 'Input signal' refers to the chopped radiance input signal to a detector element

#2.9.2 ITS OPDETPRE
The chopping waveform may not be sinusoidal; however, it is required to recover only the sinusoidal component at the fundamental frequency. The design of the chopping and signal processing subsystems shall maximise this component, and shall recover at least 85% of the total chopped signal/noise power ratio at the detector output. The OPDETPRE budget assumes that 90% is recovered.

[Analysis (see ref. 1.4.32) has concluded that the additional complexity required to make use of the relatively small amount of energy at the signal harmonic frequencies is not justified]

#2.9.3 ITS
The chopped signal shall be synchronously demodulated; the demodulated signal in each channel shall be filtered as required, converted to a digital count, sampled at the specified rate and transferred to the S/C telemetry data stream.

[It is very desirable to make an early choice of a design concept for processing the radiometric signals, as there are so many aspects of the performance which need to be specified in the IRD, the SPRAT and in the ITS. It is certainly risky, and probably impossible, to devise the wording of performance specifications which are independent of implementation]

#2.9.6 ITS
SLEW RATE: The analog signal processing electronics shall meet the performance requirements specified below for chopped input signals having an amplitude slew rate of 10% of full-scale within one chopper cycle

#2.9.7 ITS
OVERLOAD RECOVERY: Signal channel performance shall recover (i.e. so that the performance requirements specified below are met) within 12 chopper cycles following an input signal of up to twice full-scale amplitude

#2.9.11 IRD 2.5.3 ITS INSTRNEN OPDETPRE
NEN: The INSTRNEN Budget allocates allowable radiometric noise limits to the DSS (detectors + preamps). The EOL noise-equivalent radiance for each channel shall not exceed this figure when the detectors are at the upper limit of the temperature range for normal operation (see para 3.2.3)

The digitization noise shall not exceed the value allocated to the IPS in the INSTRNEN Budget.

#2.9.15 IRD 2.5.6 ITS
GAIN SETTING: each channel shall have a fixed gain setting prior to the digitiser (which is capable of being adjusted/selected on test) such that EITHER ...

i) the noise level at the digitiser input corresponds to approximately (but not less than) 10 counts pk-pk, OR ...

ii) the output count when viewing a 300K black body is 46000 +/- 10%

whichever gives the lower gain setting

[this requirement is based on that of IRD 2.5.6 plus the additional considerations detailed in refs. 1.4.28 and 1.4.29]

#2.9.17 ITS
ZERO OFFSET: each channel shall have a fixed zero offset (which is capable of being adjusted/selected on test) such that the output count when viewing a <100K black body is 2000 +/- 250.

#2.9.19 ITS
OVERALL LINEARITY: over the whole dynamic range of input signal the effective overall gain of the signal channel (excluding the detectors) shall be within 0.5% of the value at full-scale input
[see also para 2.6.7]

#2.9.21 ITS
LOCALISED LINEARITY: over any 10% portion of the whole dynamic range of input signal, the effective overall gain of the signal channel (excluding the detectors) shall not change more than 0.2%
[see also para 2.6.7]

#2.9.23 IRD 2.5.8 ITS
SAMPLE RATE: each signal output sample shall (in "global" mode) correspond to the filtered average (see 2.9.14) of an integer number of chopped signal cycles but shall be not less than 80 samples/sec. Higher sample rates, corresponding to a smaller integer number of chopped signal cycles may be required on demand [TBD]; if this option were required and selected, the total number of channels sampled shall if necessary be reduced so that the maximum specified signal data rate (ref. 1.4.5) is not exceeded. See also Ref. 1.4.55.

#2.9.27 ITS RADMETAC
GAIN STABILITY: the end-to-end gain of each channel shall not vary over time periods of 10 sec and 1 minute by more than the allowance in the RADMETAC budget, in the presence of typical orbit-rate variations in thermal flux, detector temperatures and electronics temperatures, and taking account of any variation of chopping efficiency

[This requirement relates to item #5 of the RADMETAC Budget]

#2.9.28 ITS RADMETAC
OFFSET STABILITY: the output count when viewing a zero radiance reference shall not vary over time periods of 10 sec and 1 minute by more than the allowance in the RADMETAC budget, in the presence of typical orbit-rate variations in thermal flux and electronics temperatures

[This requirement relates to items #4 and #14 of the RADMETAC Budget]

#2.9.29 ITS OUTFIELD
CROSSTALK BETWEEN RADIOMETRIC CHANNELS: the output from any 'receptor' channel shall not change by more than 1 (telemetry) count or 0.02% of the maximum specified signal for that channel (whichever is greater) as the signal input to any 'donor' channel is varied over its whole dynamic range

SECTION 3

OTHER SYSTEM ENGINEERING REQUIREMENTS & CONSTRAINTS

3.1 (this section # not used)

3.2 DETECTORS AND COOLERS

#3.2.3 ITS OPDETPRE
Each signal channel shall be capable of meeting the specified overall responsivity and noise-figure requirements given in the ITS (based on the OPDETPRE Budget) over the detector temperature range 60K to 65K.

[The proposed detector temperature range and method of operating the coolers is discussed in ref. 1.4.34]

#3.2.5 PLCR
All aspects of instrument calibration shall be known with the desired accuracy with the detector elements operating at 60K, 65K, 70K and 75K.

[In the event of serious degradation of the Coolers, it is expected that useful science information will still be obtainable up to about 70 or 75K detector temperature, provided that the pre-launch radiometric calibration data is available]

#3.2.9 ITS GSE
The Detector and Cooler Subsystems shall be so configured that it is possible for the detectors and signal channels to operate with the specified performance with the instrument in room ambient thermal conditions.

3.3 INSTRUMENT STATUS MONITORING & DATA HANDLING

#3.3.3 ITS FOCD
For instrument control purposes, every function which appears in the science telemetry stream (including 'engineering' data) shall be accessible to the subsystem control sequences (see section 3.12) in the IP, updated at a rate which is not less that the telemetry update rate

[This is considered essential to operational flexibility; it is easily implemented, and could be a disaster if not implemented and a malfunction occurs after launch]

#3.3.5 ITS FOCD
The basic telemetry data format shall be the same for all modes of operation of the instrument. Signal channel data shall be sampled at a fixed, uninterrupted rate for each instrument mode. If more than one science data format is required, the telemetry stream shall contain explicit flags indicating which science data format is in use.

[For reasons associated with the processing of both test data and operational data, it is required that a fixed data format be maintained as strictly as possible]

#3.3.7 ITS FOCD

The 'science' data stream shall include all instrument telemetry data, including 'engineering' data. The 'engineering data' packages described in Ref. 1.4.4 [GIRD] shall be a complete or subset copy of the engineering data included in the science data stream.

[For reasons associated with the processing of both test data and operational data, it is required that ALL instrument data be included within a single data stream if possible. If ancillary data streams are required on the S/C, these should duplicate subsets of the 'science' stream]

#3.3.11 ITS FOCD

The instrument telemetry data shall be valid at all times except when the instrument is in its OFF mode or awaiting initial synchronisation with the S/C clock & timing system. In the OFF mode, the telemetry data shall consist of 'zeros'

[For "health & safety" reasons it is highly undesirable that the instrument be powered with telemetry data invalid, except when unavoidable. To avoid confusion during flight operations and ground data processing, the telemetry stream should be all-zeros when un-powered]

#3.3.13 IRD 2.5.1 ITS PLCR RADMETAC

For each sensor used for monitoring temperatures other than of the IFC black body, the error in temperature inferred from telemetry count using the specified conversion algorithm shall not exceed +/- 0.25 C

[It is desirable that this be as good as possible, without unduly 'driving' the design. The figure given here is based on engineering judgement and will meet the requirements of the RADMETAC Budget]

#3.3.15 IRD 2.5.1 ITS PLCR RADMETAC

For each temperature sensor used for monitoring IFC black body temperature, the error in temperature inferred from telemetry count using the specified conversion algorithm shall not exceed 40 mK at EOL

[This requirement relates to item #0 of the RADMETAC Budget. A further 30 mK is allowed for pre-launcg cal. error, giving the total of 70 mK uncertainty]

#3.3.17 ITS FOCD

Sun sensors shall be used in combination to monitor the operation of the sunshield as follows:

> to detect whether the instrument is in 'day' or 'night';
> to indicate when the sun is illuminating the -X face of the instrument such that it could potentially shine into the instrument aperture;
> to detect the position of the edge of the shadow cast by the sunshield in order to verify that the sun shield is so positioned as to reliably meet the requirement given in 2.6.31;
> each sensor shall be monitored by telemetry at a sample rate of at least 1 per second.
> these sensors shall be independent of the sunshield angle sensor referred to in para. 2.6.33

[Three possible control modes for the sunshield door may be envisaged.
First, the door is driven from a look-up table in the IPS (generated on the ground and uplinked) and the sun-sensor data are used on the ground to verify correct operation.

Second, the door is driven from a software routine in the IPS which uses the sun-sensor information to determine when drive pulses to the door motor are required, and in which direction.

Third, some combination of the above, where the sun-sensor information would probably be used to provide a limit over-ride function, etc.

These options will be available/chosen after launch and do not directly affect the design and positioning of the sensors]

#3.3.21 IRD 2.10.4 ITS

The instrument signal data strea m shall contain a time mark or marks, derived from the S/C master clock, from which it shall be possible unambiguously to derive the time of each sample of the below listed channels ...

a) each signal data channel,
b) each gyro data channel,
c) each scan angle transducer channel,

... with an uncertainty of 2 parts in 10E6 or +/- 0.2 msec, which ever is less.

If the expected accuracy of the S/C clock signal is insufficient to meet the above requirements, then an internal higher-precision frequency source shall be provided, the relationship between the latter and the S/C time being reported via telemetry with sufficient resolution to meet the above requirements.

[There is no requirement for synchronisation with a data frame period, since the instrument data is asynchronously transferred to the S/C data bus, and instrument data timing needs only to be internally consistent. The chopped-signal frequency will be used as the 'master clock' for the purpose of controlling signal and other data channel sampling. Each data block (TBD but probably one per 12 msec approximately) needs to be time-tagged from a high-frequency crystal-controlled clock (normally provided by the S/C) so that the data sample timing can be reconstructed on the ground.

There is likely to be an operational desire/need to divide the orbit period into an integral number of scan cycles (around 92) in global mode at least, synchronised to the ascending node marker. This requires no special provision as it will be controlled by the programmable software in the IP]

#3.3.23 (SPRAT)
Additional status monitor functions may be required to fulfil the requirements of Section 3.5 below

3.4 INSTRUMENT CONTROL REQUIREMENTS

#3.4.1 FOCD GSE
Instrument ACTIVATION in orbit from a power-off condition shall be accomplished by running a specified SEQUENCE of procedures in the Payload Operations Control Centre (POCC). Such procedures shall contain the necessary commands, microload directives and telemetry checking routines considered necessary to ensure safe instrument activation. The design of the instrument control software shall be compatible with this approach. See also para. 3.5.9.

[This requirement is based on recent UARS experience and knowledge (as far as it is available) of the likely operational environment for the EOS payload, which is being developed to a large degree from UARS flight operations experience]

#3.4.2 IRD 2.9 ITS FOCD
A single Instrument Processor (IP) shall be used to store automatic control sequences and to provide these sequences with access to the instrument data stream for conditional or adaptive operation. At least the following instrument functions shall be controlled from the IP:-

> sunshield door mode and position
> elevation scan parameters
> azimuth scan parameters
> signal channel reference phase settings
> digital signal filter parameters
> signal data format (assignment of channels to data slots)
> thermostat settings and control parameters
> cooler compressor amplitude settings
> fault detection and protection as appropriate

[The intention of this paragraph is that, although additional processors may be used within individual subsystems e.g. for servo-control purposes, control of overall instrument modes and settings shall be vested in a single processor, and no additional commands, microloads, memory dumps or other routine flight operations shall be required due the use of such additional processors]

#3.4.3 ITS FOCD

The IP shall include (in a non-volatile ROM) the essential on-board 'system' software to allow full operation of the instrument command and telemetry functions. Such ROM routines shall be installed as late as possible in the instrument calibration program, prior to delivery of the instrument to the S/C integrator.

3.5 INSTRUMENT MODES AND ACTIVATION

#3.5.1 ITS FOCD

Terms used in this section are formally defined as follows:-

> MODE - a Mode is an Instrument attribute, and is defined as a steady-state condition in which the instrument subsystems are in defined States. See footnote.

> SUBMODE - a Submode is an Instrument attribute, and is defined as an infrequently used, modified set of States associated with one - or more than one - Mode.

> STATE - a State is a Subsystem attribute; Subsystem States are given here to the extent that they have been defined.

> TRANSITIONAL MODE - a Transitional Mode will occur following a Mode-change command. In a Transitional Mode, Subsystem States may be changing (e.g. booting). Transitional Modes usually occur during Instrument Activation. See footnote.

> INSTRUMENT ACTIVATION - Instrument Activation is the term used to describe the sequential process of powering the instrument - usually from the OFF Mode - in a controlled manner, by means of an Activation Sequence.

> ACTIVATION SEQUENCE - an Activation Sequence is a pre-programmed series of HIRDLS commands, time delays, telemetry checks and other conditional expressions which will be written in STOL (System Test & Operations Language). STOL Sequences will be run on the HIRDLS IEGSE or OGSE (Observatory Ground Support Equipment) during Instrument test, and in the POCC (Payload Operations Control Center) after launch.

FOOTNOTE:- steady-state instrument temperature is NOT a required State or Mode attribute, except for Mission Mode.

#3.5.3 ITS FOCD
The following table IDENTIFIES the Instrument (non-Transitional) Modes and Submodes, and DEFINES the associated State attributes in general terms:

MODE NAME	DESCRIPTION & ATTRIBUTES	POSSIBLE SUBMODES
OFF	HIRDLS QB, NB and SHB power off at S/C i/f	DEFAULT CAGED SAFE SAFE+CAGED
SURVIVAL	HIRDLS QB and NB power off at S/C i/f; SHB power on	DEFAULT CAGED SAFE SAFE+CAGED
IDLE	End of first stage in Activation Sequence:- IPU & TEU data systems powered; telemetry data valid; status monitoring valid; command handling enabled; all other functions powered down, incl. all operational heaters; no SAIL Tasks or Tables loaded.	DEFAULT CAGED SAFE SAFE+CAGED
LOW POWER	End of second stage in Activation Sequence: IPU & TEU data systems powered; telemetry data valid; status monitoring valid; command handling enabled; SAIL Tasks & Tables loaded & verified; all other systems (incl. heaters) powered down	DEFAULT CAGED SAFE SAFE+CAGED
	End of third stage of Activation Sequence:-	

STANDBY_1	all electronics powered; operational heater status unde-fined; mechanisms inhibited; detectors warm or warming;	DEFAULT SAFE DECONTAM DECONTAM+SAFE
STANDBY_2	Warmup for Decontam or cooldown: ready to transition to Mission:- all instrument systems powered; all operational heaters on; all mechanisms enabled but not oper-running (except Coolers); detectors cold, cooling or warming; temperatures stabilising or stabilised	DEFAULT SAFE DECONTAM DECONTAM+SAFE
MISSION	all instrument systems powered; all operational heaters on; detectors cold; all mechanisms enabled and operational; all temperatures stable	DEFAULT SPECIAL

#3.5.5 ITS FOCD

The following table DEFINES the attributes for the above-listed Submodes, and shows to which Modes they apply as options:

SUBMODE NAME	DESCRIPTION & ATTRIBUTES	POSSIBLE IN FOLLOWING MODES
DEFAULT	All Mode attributes "normal"	(ALL)
CAGED	Instrument readied for shake-testing or launch:- Sunshield door latched; Scanner elev motors caged; Space View Aperture door closed; Cooler compressor drive coils caged	OFF SURVIVAL IDLE LOW POWER
SAFE	Instrument safed against poss-solar influx and thruster fuel contamination:- Sunshield door closed (Caged or uncaged) OR in Safe (60 deg) position; Scan mirror Caged or uncaged and in any position if Sunshield door closed, OR in IFC view position with drive motors unpowered (both axes); Space View Aperture door closed. space-view aperture door closed;	ALL EXCEPT MISSION
DECONTAM	Cryo surfaces not being cooled; accreted ice (if any) subliming: Cooler displacer inhibited; make-up heaters on; compressor operation optional	STANDBY_1 STANDBY_2
SPECIAL	Subsystems configured for spec-calibrations, science-related special scanning modes, etc.	MISSION

#3.5.9 ITS FOCD

Instrument Modes and States must be consistent with the Activation Sequences. The following is a preliminary outline of the basic HIRDLS Activation Sequence. As a more detailed sequence is developed it will be written into Ref. 1.4.7 - Flight operations Concept Document (FOCD):-

```
> BEGIN  {if >1.5 mins remain}          {first stage: OFF ---> IDLE}
  > HIRDLS QB POWER ON (A or B side)
                     {all IPU power rails and PCU 5V supply come up}
  > WAIT 5 seconds  {for Instrument Processor (IP) to start booting}
  > VERIFY IP booting
  > If not OK then EXIT
  > WAIT 30 sec                        {for IP to complete booting}
  > VERIFY IP running
  > If not OK then EXIT
  > RESET ALL POWER RELAYS
  > INTERNAL +28Q POWER ON (A or B)       {close non-latching relay}
                            {power for Scan Processor (SP) comes up}
  > SYSCONV POWER ON (A or B side)    {+5, +/-15V "system" supplies}
  > WAIT 5 sec                            {for SP to start booting}
  > VERIFY SP booting
  > If not OK then EXIT
  > WAIT 30 sec                        {for SP to complete booting}
  > VERIFY SP running
  > VERIFY SYSCONV supplies within limits
  > END                      {first stage:  HIRDLS now in IDLE Mode}


> BEGIN  {if >TBD mins remain}   {second stage: IDLE ---> LOW POWER}
  > START SAIL processor
  > UPLINK/VERIFY SAIL Tables
  > UPLINK/VERIFY SAIL Tasks
  > START (TBD) SAIL Tasks             {if applicable in this Mode}
  > +28V CONV POWER ON (A or B side)      {+28V internal reg. power}
  > VERIFY LOW POWER Mode status
  > END                {second stage:  HIRDLS now in LOW POWER Mode}
```

/continued . . . .

```
> BEGIN  {if >4 mins remain} {UNCAGE procedure} {Caged Submode only}
  > START SAIL UNCAGE Task
  > WAIT TBD seconds
  > Verify UNCAGED status
  > END                                            {HIRDLS now UNCAGED}

> BEGIN {if >TBD mins remain}{third stage: LOW POWER ---> STANDBY_1}
  > {TBD}
  > Verify STANDBY_1 Mode status
  > END                {third stage:  HIRDLS now in STANDBY_1 Mode}

> BEGIN {if >TBD mins remain}{fourth stage: STANDBY_1 --> STANDBY_2}
  > ENABLE/VERIFY remaining power circuits
  > START TBD SAIL Tasks                         {heater control; etc}
  > TBD
  > Verify STANDBY_2 Mode status
  > SET "transition to Mission Mode" option         {AUTO or MANUAL}
  > END      {fourth stage:  HIRDLS now in STANDBY_2 Mode pending
                                  automatic transition to Mission Mode}

> BEGIN  (if >TBD mins remain} {fifth stage: STANDBY_2 ---> MISSION}
  > {only required if manual transition desired}
  > TBD
  > END {fifth stage:  HIRDLS now in MISSION Mode}
```

#3.5.17 GIRD 3.9 ITS

Mechanisms which require caging for launch shall be capable of being uncaged by command, and in all cases both the caged and uncaged conditions shall be explicitly verifiable by telemetry.

Mechanisms may be capable of being caged by command, for which purpose it may be assumed that all spacecraft power supplies (A or B side) are available. Such mechanisms are not required also to be capable of being caged manually.

Any mechanism requiring caging for launch, and for which the caging must be performed manually, shall be capable of being caged with no power available. Such mechanisms shall be capable of clear visual verification of the caged condition.

#3.5.19 GIRD 4.2 ITS FOCD

The term Survival is defined here as the ability of the instrument fully to recover from any temporary externally-imposed environmental or other condition, for which the instrument is not designed on the basis of its normal operating requirements.

Environments to be survived are given in the GIRD, section 4.2.2. It shall be possible to re-activate the instrument from a Survival condition through Mission Mode with no loss of performance following an indeterminate period in the Survival condition.

#3.5.21 UIID 3.3 ITS

Minimum survival temperatures shall be defined for each subsystem; individual thermostat-controlled heaters shall be sized and located, and set-points determined, such that they will indefinitely ensure instrument survival in any S/C orientation in which any instrument minimum temperature limit would otherwise be violated.

Heaters shall be sized such that an on-failure of any one heater does not raise the temperature of the item to which it is attached by more than 10 C under Mission Mode conditions, or reduce the radiometric accuracy of the instrument.

Thermostat set points shall be chosen to eliminate, or at least minimise, the probability of continuous on/off cycling under steady-state conditions in Mission Mode or in the Survival condition.

Survival heater power requirements shall be the minimum necessary to meet these conditions, a design aim being to meet the requirement of Ref. 1.4.4 [GIRD] for mean survival power not to exceed 30% of normal mean operating power, and in any case not to exceed the survival power allocation given in the UIID (ref. 1.4.5)

Two complete sets of survival heaters shall be fitted, each set alone providing the required heat dissipation. One set shall be wired to each of the A and B Survival Heater Buses. Each set shall independently be capable of being connected and disconnected by command from its Heater Bus

Survival heaters shall be electrically isolated from other instrument circuits, and shall interface only with the S/C supplies provided for this purpose. Heater/thermostat set-points shall be preset (fixed) and independent of any other instrument subsystem. No additional control electronics shall be used

3.6 FAULT DETECTION AND PROTECTION

The HIRDLS instrument may be in one of two states with respect to fault vulnerability, i.e. IP operating, and IP not operating. Accordingly the following measures are required to minimise the risk of a permanent malfunction within the instrument:

#3.6.3 ITS EID FOCD

In the condition where the IP is NOT OPERATING and cannot therefore provide any automatic fault detection, protection against the following hazards (at least) may need to be provided:

a) Protection against below-minimum temperatures: the condition in which instrument temperatures are in danger of falling below survival limits can be detected by the S/C by the use of the full-time ("Passive") temperature sensors. A S/C telemetry monitor response (TMON) can initiate a relative time sequence (RTS) installed in the S/C OBC containing a command or commands to turn on the HIRDLS SHB (it is assumed that this condition will only occur if SHB power to HIRDLS is off)

b) Protection against hazardous malfunctions: fault conditions may be identified (e.g. electrical overload) which could result in consequential damage if not removed in a timely way. Passive temperature sensor channels, or - if these are inapplicable - bi-level or analog telemetry signals may be provided directly to the S/C (i.e. NOT using the 1553 interface) and used to generate TMONs to initiate one or more RTS as required to remove power or otherwise make safe the detected fault condition

#3.6.5 ITS FOCD

In the condition where the IP IS OPERATING and can provide automatic fault detection, fault conditions may be identified which could result in consequential damage if not removed in a timely way.

Such conditions should be monitored by telemetry, and appropriate IP tasks and command sequences (macros) provided in order to make safe the detected fault condition.

Enable/inhibit commands must be provided for each such task/macro.

3.7 ELECTRICAL REQUIREMENTS, INTERFACES AND CONSTRAINTS

#3.7.5 ITS

The electrical connections between the Detector Dewar and the Preamplifier modules shall be fully enclosed within a shield which is grounded to the chassis of both modules. Connectors shall not be used at this interface.

#3.7.13 ITS

Movement of the sunshield door shall not create electromagnetic disturbances within the instrument that interfere with the continuous and undegraded acquisition of Science Data.

3.7.15 Motors and drive systems shall meet the stall requirements described in SPRAT para. 3.8.9.

3.8 THERMAL REQUIREMENTS, INTERFACES AND CONSTRAINTS

#3.8.1 ITS FOCD

The use of active thermosat-heaters is allowed where necessary to enable specific temperature or stability requirements to be met, unless otherwise stated. Any operational (i.e. not survival) heater shall be capable of operating in either of two modes, i.e.

a) Thermostatic Mode: in which the heater dissipation is controlled by software in order to maintain a demanded control sensor temperature, and where the control law has (the usual) three programmable terms, and

b) Constant Dissipation Mode: in which the heater dissipation is set via software to a constant value selectable by command in the range zero to >90% in 1%, or smaller, steps

#3.8.5 ITS FOCD

During instrument decontamination (see para. 3.5.1) it is expected that the Cooler compressors will continue to be operated at nominal stroke, but that displacer operation will be inhibited. In this condition both the compressors and the displacer will dissipate significantly less heat.

In order to maintain steady-state instrument temperatures during decontamination, it will be necessary to fit compensating heaters to the Cooler Subsystem. These will be cycled on-off as required by the IP.

[If the instrument is allowed to cool significantly during decontamination, the period for which radiometric data will be invalid will be extended by up to 12 hours, which is considered unacceptable]

#3.8.9 SPEC ITS
Ref. 1.4.3 contains the following requirement:-

4.5.3.2 Motor Stall Vulnerability
Drive motor(s) shall not be damaged if powered with start-up currents under locked rotor conditions in an air or vacuum environment for 30 minutes. The drive motors shall not be damaged by any available shutdown mode or sequence.

This requirement may be re-worded for HIRDLS as follows:-

Any motor whose body outer temperature could rise by more than 20 degrees if continuously powered under locked rotor conditions shall be fitted with a temperature sensor connected to telemetry, and shall be capable of being powered down by the IP.

In the condition where the motor is continuously powered to the maximum possible extent with the rotor locked, it shall not be damaged, or its performance degraded, as a result of the heat dissipation occurring between the application of power and the subsequent removal of power by the IP on detection of a rise in body temperature of TBA degrees [to be agreed with motor circuit designer].

#3.8.15 FOCD RADMETAC
The mean temperatures of the IFC black body and of the IFC paraboloid mirror shall be maintained to within [TBD] (1 deg. C) of each other

The emissivity of the IFC paraboloid shall be determined before launch and known at all times prior to EOL to within the accuracy specified in the RADMETAC budget.

[These requirements relate to items #1 and #2 of the RADMETAC Budget. If these two items are at held the same temperature, most of the potential radiometric calibration errors associated with indirectly viewing a small IFC target body are eliminated. The use of a full-aperture target, with its accompanying difficulties in respect of accuracy and accommodation, is thus avoided]

#3.8.17 ITS
The mounting faces of the electronics units (when dissipating their stated nominal power under normal operating conditions) shall each be maintained at a mean temperature compatible with the requirements of the instrument Reliability Budget

The temperature variation of the Cooler and Electronics mounting faces over the period of one orbit shall not exceed 5 deg. C peak-to-peak for analog electronics and 10 deg. C peak-to-peak for digital electronics

[It is important for good radiometric calibration stability that the general internal ambient temperature of the instrument, as well as of the electronic circuits, be as constant as possible. The target figures given above for temperature stability are based on electronic performance considerations and on thermal math. modelling indications of what should be attainable without unduly 'driving' the instrument size or weight]

#3.8.25 PLCR

Control of the thermal environment during instrument calibration in vacuum shall be such that:

a) 'critical' instrument temperatures can be maintained within 2 deg C of their predicted nominal operational values in orbit, and at any other selected temperatures within +/- 10 deg C of nominal;

b) 'non-critical' instrument temperatures may be maintained within 5 deg C of their predicted nominal operational values in orbit, and at any other selected temperatures within +/- 20 deg C of nominal.

All instrument temperatures which are actively controlled (i.e. by means of programmable thermostats) shall be capable of being increased by at least 10 deg C above their nominal values with nominal external thermal boundary conditions

Instrument calibration procedures shall be performed at - at least - the minimum and maximum predicted operational (in-orbit) values of instrument critical temperatures, with a 5 deg C margin added at each end, and at as many additional intermediate temperature settings as necessary adequately to characterise instrument performance over the said temperature range.

NOTE: 'critical' instrument temperatures shall be identified during the instrument development program; temperatures not so identified shall be assumed to be 'non-critical' for the purposes of this requirement.

3.9 ENVIRONMENTAL, PERFORMANCE ASSURANCE & TEST REQUIREMENTS

#3.9.3 OUTFIELD CONTAMIN

The maximum incoherent optical scattering allowed by the OUTFIELD Budget (section 4.3) corresponds to an accumulated particulate contamination EOL value of "Level 400" per MIL-STD-1246B. To meet the above target figure, critical optical surfaces must be kept cleaner than the specified EOL limit, as given in the CONTAMIN Budget (section 4.2)

#3.9.5 ITS PLCR EID CONTAMIN

To meet the EOL target figure given in para. 3.9.3, at each of the specified program stages particulate contamination of critical instrument surfaces shall not exceed the levels shown in the CONTAMIN Budget (section 4.2)

If cleaning procedures are required in order to meet any of these levels, the instrument must be designed to allow this, and suitable procedures must be defined.

#3.9.7 GSE

Instrument GSE shall be provided to enable instrument operation in any orientation in a room ambient environment for a continuous period of at least 48 hours without exceeding any subsystem maximum operating temperature. 'Ambient' should be assumed to imply an air temperature of 21 +/- 5 deg, and a relative humidity of 50 +/- 20%

Any air or gas-flow arrangements, detachable cooling plate[s], etc. which may be needed during these tests shall form part of the thermal GSE and must be compatible with any applicable safety and environmental requirements.

[This applies to 'bench' testing, and perhaps even more, to S/C compatibility testing, where extended test periods are required. In practice, '48 hours' probably implies an indefinite period]

#3.9.11 ITS PLCR EID

The instrument housing shall be configured to prevent the ingress of particulates into the optical system, especially when the instrument is in an increasing-pressure environment. This requirement applies both to functional and to incidental apertures in the instrument outer housing.

Hermetic sealing of apertures is not required; however, all apertures shall be closed for launch, except for venting arrangments which shall be included to prevent excessive pressure differential between the outside and inside of the instrument housing or any enclosure within the instrument which is not intentially hermetically sealed.

Outward venting, away from HIRDLS optical and passive thermal control surfaces other instrument or spacecraft surfaces, will be required during launch and for ground testing. Appropriate outward venting cross-section areas shall be determined. External vent locations shall be approved by the Spacecraft Contractor, and vent details documented in the instrument ICD.

Any un-sealed (e.g. electronics) enclosure within the Optical Bench Assembly having an internal volume of 30 ml or more shall be vented directly to the exterior of the instrument structure.

Inward venting will be required following a period of exposure to vacuum during instrument testing, or during shipping & transportation. During inward venting, > 95% of air or gas entering the outer housing, and > 99% of air or gas entering the optical system, shall have passed through (a) suitable filter(s) which will trap any particle > 5 microns in size. Appropriate outward venting cross-section areas shall be determined.

Pumping apertures of any size and other non-radiometric apertures of area greater than 5.0 mm2 shall be covered during launch by a fixed mesh filter sized to block the passage of particles larger than 0.5 mm diameter and to obscure the aperture area by no more than 20%.

Radiometric apertures shall be protected during launch by covers which can be opened on command, but unless otherwise specified, need not be reclosable on command. For vents required only to accommodate the launch pressure profile, the closure requirement may be met by a spring-loaded flap opening outward.

#3.9.15 ITS GSE

Sunshield door operation in all instrument orientations in a 1g field is NOT required. However, it shall be possible fully to open and close the door by command, using power supplied from the S/C and without GSE, with the instrument Z axis within 30 degrees of the vertical

Use of GSE to operate the door or hold the door open in other orientations is permitted

#3.9.19 ITS PLCR

Prior to launch the instrument shall be exposed only to environments which meet the requirements of ref. 1.4.13. The Main Aperture door (moveable sunshield) and Space View Aperture cover shall remain closed and latched except:

(i) when tests are to be conducted on the above mechanisms;
(ii) when the instrument is required to view an external target or is to undergo optical alignment or calibration checks, etc.

#3.9.21 GSE

The Instrument shipping container shall be designed to meet the following requirements [see note 1]:-

	Limits	See note
Thermal insulation:		2
Relative Humidity:	0% to 65%	3
Pressure:	vacuum to 1.2 atm.	3
Vibration:		4
Acceleration/shock:		4
Orientation:	none	5
Cleanliness:	Fed. 209 Class 20	6

Notes
-----

1. Only system-derived requirements are given here. All additional requirements shall be identified and documented in ref. 1.4.15

2. Thermal insulation shall be provided, such that the instrument temperature within the container cannot rise or fall faster than 1 K/hour per 10 K temperature differential between the inside and the outside. While exposed to direct sunlight from any one direction this rate may be permitted to increase by not more than a factor 2.

3. These limits shall not be exceeded in the worst case where the container is filled with gas at 25C, prepared for shipping, exposed to a 30C environment for 1 week and then to a -50C environment for 1 week, during which 2-week period the container is air-freighted at 40,000 feet altitude for 12 hours in an un-pressurised hold.

4. The instrument shall be fitted to shock-absorbing mounts having the following performance parameters:- TBD

5. The mounting interface shall be designed to support the instrument in any orientation of the container. The clearance between the instrument and the container shall never be less than 20 mm when prepared for shipping.

6. Applies when the instrument is double-bagged. When only the inner bag is in place the environment shall be Class 10,000 or cleaner.

SECTION 4

ALLOCATION BUDGET TABLES

4.1 RATIONALE, PRECEDENCE & TRACEABILITY

Rationale

In compiling the HIRDLS instrument-level budgets (all of which relate to IRD requirements) it has been assumed that the various errors (pointing, FOV, spectral, radiometric, etc) are allowed by the IRD to co-exist with appropriate probabilities, and are in effect members of a "hidden" IRD-level budget.

Thus each of the instrument-level budgets herein ignores any error sources which are included in other instrument-level budgets and/or separately addressed in the IRD. For example, the effect of allowed spectral knowledge errors (IRD 2.4.2) on radiometric accuracy have NOT been included in the radiometric accuracy budget (RADMETAC).

Precedence

Relatively simple budgets, the derivation of which can be simply described, are documented only in the SPRAT, section 4. The more complex budgets are summarised in the SPRAT, section 4, and are documented in detail in separate 'TC's as indicated. Where there is any conflict between the values shown in the 'TC' and the values shown in the SPRAT, the more recently dated document shall take precedence.

Traceability

The Budget tables in this section of the SPRAT are referenced in the SPRAT BUDGET column of the traceability table in section 5. An entry in BOLD indicates the source document and paragraph from which the Budget is derived. Other entries for that Budget correspond to the individual line items. SPRAT paragraph numbers are shown explicitly. Destination document para. numbers are not shown at this time but may be added later.

4.2 CONTAMIN BUDGET

Description: This budget allocates the fraction of the allowable EOL accumulated particulate contamination which is acceptable at each of the given stages in the HIRDLS instrument program.

Stage/milestone	Level per MIL-STD-1246		Accumulated Fraction of EOL obscuration
Completion of I & T in USA:	280	*	28 %
Completion of calibration in UK:	300	*	38 %
At launch:	330	*	58 %
After 5 years in orbit (EOL):	370		100 %

NOTE: * these are provisional levels at major milestones only and are intended for guidance. They may be modified in the light of future analysis of particulate contamination scenarios, cleaning procedures and opportunities.

4.3 OUTFIELD BUDGET SUMMARY

Description: This budget addresses the IRD limit for the maximum acceptable out-of-field signal. At this instrument system level the IRD requirement has been divided into four parts corresponding to four different stray-light mechanisms, and the allocated amounts adjusted during the development of the corresponding analyses. It should be noted that this allocation process is somewhat crude in the sense that several of the stray-light mechanisms are strongly wavelength-dependent and/or field-position-dependent and/or elevation-scan-angle-dependent. The allocations are therefore useful only as a guide to the level of attention to be paid to the suppression of each source of stray-light. Ultimately the total out-of-field strays need to be assessed for each channel over its specified elevation scan range. This has been done for incoherent optical scattering and is reported in ref. 1.4.43

See note 5: ------->	Col. A		Col. B			
Percentage of:	SIG	NEN	SIG	NEN	see note	SPRAT PARA
Maximum contribution from multiple reflections within optical system:	0.02%	5%	0.02%	5%	1	2.4.16
Maximum contribution due to diffraction from out-of--field sources:	0.08%	10%	0.32%	25%	3	2.4.17
Maximum contribution from incoherent optical scattering:	0.28%	75%	0.04%	60%	3	2.4.18
Maximum contribution from electrical "crosstalk":	0.02%	10%	0.02%	10%	2	2.9.29
Arithmetic sum:	0.40%	100%	0.40%	100%		
IRD requirement:	0.40%	100%	0.40%	100%	4	2.4.15

Notes
-----

1. The relatively small allocation reflects the current design concept in which all transmitting components are placed between conjugate bandpass filter pairs. For detail see ref. 1.4.46.

2. The relatively small allocation is based on the assumption that this effect can be reduced to an arbitrarily low level with careful design

/continued . . . .

3. The large differences between the figures in col. A and col. B illustrate the sensitivity to elevation scan angle, i.e. tangent point altitude. For details of the scatter analysis see refs. 1.4.40, 1.4.43 and 1.4.45. For details of the diffraction analysis see refs. 1.4.47 and 1.4.48.

4. The IRD gives 100% of NEN as the "requirement".

5. Col. A is allocation for high-altitude "worst case" (channel 20 @ 50 km); Col. B is allocation for low-altitude "worst case" (channel 1 @ 10 km); other channels are somewhere in between

4.4 IFOVKNOW BUDGET

Description: the IRD requirement for KNOWLEDGE of the vertical IFOV profile shape at EOL implies maximum acceptable overall errors in both response amplitude and vertical position/angle, which have been allocated to individual potential error sources as shown in the following table (note 1):

ERROR SOURCE	TO:	ALLOWANCE		UNIT	NOTE	SPRAT PARA
Uncertainty due to imperfect pre-launch characterisation	PLCR	0.5		%		2.4.21
			1.0	arc"	2	2.4.21
Possible change in VIFOV profile after characterisation due to e.g. focus changes	ITS	0.5		%		2.4.23
Possible "static" change in angular registration relative to centre channel	ITS		1.0	arc"	3	2.4.25
Arithmetic sum			2.0	arc"	4	
IRD requirement		1.0		%		2.4.20
			2.0	arc"		

NOTES

1. This budget addresses only KNOWLEDGE of the VERTICAL FOV for each channel. The HORIZONTAL FOV requirements are sufficiently loosely specified that a budget is not required.

2. The IRD requirement has been interpreted as meaning that the relative response shall be known to +/- 1% of the peak response, averaged over any 7 arc second (one tenth of a channel VIFOV) interval at the entrance pupil.

3. The angular "registration" of the VIFOV measurements relative to the boresight is effectively determined by the requirement of IRD para 2.6.3.2.

4. The error allowances have been summed arithmetically, since there are only two items

4.5 PASSBAND BUDGET SUMMARY [For derivation see ref. 1.4.37]

Description: Although not a 'budget' in the usual sense, the spectral passband profile requirement for each channel is influenced by several factors in addition to the Warm Filter which is the primary bandpass-defining component. The overall passband results from the combined effect of all these components, whose spectral response functions interact in a generally multiplicative way.

The family of 21 PASSBAND Budgets for the 21 channels forms part of the HIRDLS spectral design spreadsheet generated by Reading University. It is not practicable to extract a summary table of any useful kind from this spreadsheet.

4.6 BLOCKING BUDGET SUMMARY [For derivation see ref. 1.4.37]

Description: Although not a 'budget' in the usual sense, the spectral out-of-band response ("blocking") profile requirement for each channel is influenced by several factors in addition to the Cold and Warm Filter which are usually considered to be the primary blocking components in the optical system. The overall blocking profile results from the combined effect of all these factors, which interact in a generally multiplicative way.

The family of 21 BLOCKING Budgets for the 21 channels forms part of the HIRDLS spectral design spreadsheet generated by Reading University. It is not practicable to extract a summary table of any useful kind from this spreadsheet.

4.7 SPECKNOW BUDGET SUMMARY [For detailed derivation see ref. 1.4.49]

Description: the IRD requirement for knowledge of the spectral bandpass profile of each channel implies a maximum acceptable overall error in the relative response amplitude which has been allocated to individual potential error sources as shown in the following table:

ERROR SOURCE	TO:	3-sig ERR ALLOWANCE SPECT/FREQ		AMPLIT	SPRAT PARA
(a) Uncertainty in pre-launch calibration relative response amplitude:	PLCR	---		0.5 %	2.5.7
(b) Permanent frequency shift in passband edges after characterisation:	ITS	0.1 w/n	=	1.0 %	2.5.9
(c) Permanent changes in pass-band profile amplitude after characterisation:	ITS	---		0.5 %	2.5.9
(d) Uncorrected temperature-induced frequency shift in passband edges during lifetime:	ITS	0.04 w/n	=	0.4 %	2.5.9 (note 5)
(e) Temperature-induced variation in bandpass profile amplitude during lifetime:	ITS	---		0.2 %	
Sum (see note 1):				1.4 %	
Sum (see note 2):				1.3 %	
Sum (see note 3):				0.9 %	
IRD requirement:				1.0 %	2.5.6

NOTES

1. Items (d) and (e) are assumed worst-case correlated (additive, i.e. 0.6%), this figure being root-square summed with items (a), (b) and (c).
2. All items root-square summed.
3. As Note 1, but item (b) omitted
4. Strictly, the error sources described above as being within the TSS are, to a small extent, also present within the DSS. However, for the purposes of these Budget allocations, contributions from the DSS are considered negligible.
5. Corresponds to 0.16 w/n shift before correction (ref. 1.4.49)

4.8 INSTRNEN BUDGET

Description: This budget allocates radiometric noise allowances for each channel to the three major instrument subsystems involved in radiometry, the Detector Subsystem, the Telescope Subsystem and the Instrument Processor Subsystem

The Detector Subsystem radiometric/noise performance is tabulated in more detail for each channel in the OPDETPRE Budget. Systematic radiometric errors are tabulated in the RADMETAC Budget

/ see next sheet . . . . .

CHAN #	GAS	WAVELENGTH (micron) cut on	WAVELENGTH (micron) cut off	Spect. width %	Note a RADIANCE FROM 300K BB (W/m^2/ster)	Note b MAXIMUM RAD NOISE at e/pupil x 10^-4	Note c MAXIMUM BB SIGNAL-to-NOISE RATIO	Note d MAXIMUM ATM SIGNAL-to-NOISE RATIO	Note e ALLOCATION to TSS at e/pupil x 10^-4	Note f ALLOCATION to IPS at e/pupil x 10^-4	Note g ALLOCATION to DSS at e/pupil x 10^-4	CHAN #
1	N2O/Aero	17.01	17.76	4.34	3.9	12	3250	1371	0.27	1.73	11.87	1
2	CO2	16.26	16.67	2.47	2.34	6.3	3714	1241	0.24	0.91	6.23	2
3	CO2	15.65	16.39	4.64	4.66	5.9	7898	2398	0.47	0.85	5.82	3
4	CO2	15.15	15.97	5.29	5.25	6	8750	3247	0.63	0.87	5.90	4
5	CO2	14.71	15.27	3.75	3.82	4.3	8884	4009	0.78	0.62	4.18	5
6	Aero	11.96	12.18	1.81	1.98	1.9	10421	1495	0.29	0.27	1.86	6
7	CFC-11	11.72	11.98	2.13	2.33	2	11650	1963	0.38	0.29	1.94	7
8	HNO3	11.05	11.63	5.10	5.51	4.2	13119	4161	0.81	0.61	4.08	8
9	CFC-12	10.72	10.93	1.95	2.07	2	10350	1947	0.38	0.29	1.94	9
10	O3	9.95	10.15	2.01	2.04	1.5	13600	2971	0.58	0.22	1.37	10
11	O3	9.35	9.80	4.78	4.64	2.4	19333	4775	0.93	0.35	2.18	11
12	O3	8.77	8.93	1.77	1.56	0.96	16250	3445	**0.67**	0.14	**0.67**	12
13	Aero	8.20	8.33	1.65	1.3	1.1	11818	2752	0.54	0.16	0.95	13
14	N2O5	7.94	8.14	2.49	1.86	1.1	16909	3226	0.63	0.16	0.89	14
15	N2O	7.80	7.96	2.05	1.47	1.1	13364	1797	0.35	0.16	1.03	15
16	ClONO2	7.70	7.82	1.63	1.13	1.1	10273	1171	0.23	0.16	1.06	16
17	CH4	7.30	7.55	3.34	2.1	1.2	17500	2443	0.48	0.17	1.09	17
18	H2O	6.97	7.22	3.55	1.97	1.2	16417	2433	0.47	0.17	1.09	18
19	Aero	7.06	7.13	0.99	0.56	1.3	4308	725	0.14	0.19	1.28	19
20	H2O	6.49	7.03	8.10	3.91	1.6	24438	579	0.11	0.23	1.58	20
21	NO2	6.12	6.32	3.23	1.18	1.1	10727	892	0.17	0.16	1.07	21

Notes

a This column copied from IRD Table 1. B/W = 7.5 Hz.

b This column copied from IRD Table 1. Units: watts/m^2/ster. Independent of chopped signal amplitude. B/W = 7.5 Hz.

c This is the ratio of the previous two columns.

d This column, copied from TC-OXF-89, gives the maximum signal/noise ratio for atmospheric signals

e This number represents the maximum radiometric noise allocation to Chopper-induced noise (the Chopper is part of the TSS). This is assumed proportional to chopped signal amplitude, and is based on a minimum chopped-signal/noise ratio of 5125 in all channels, the driver being the channel having the maximum ATMOSPHERIC-signal/noise ratio per unit total NEN (channel 12), such that the allowable noise is approximately equally divided between chopper-induced noise and DSS noise.

f The noise component allocated to the IPS to allow for "digitisation noise" is NEN/2¦12. This assumes that the signal channel gain is set so that the quantisation step size is approximately equal to half the RMS input noise level (= approx 10 counts p-p)

g This number represents the maximum radiometric noise allocation to the OPDETPRE budget (detector + preamp noise). It is the RSS-remainder after subtracting the above "IPS" and "TSS" allocations.

4.9 OPDETPRE BUDGET SUMMARY [For detailed derivation see ref. 1.4.41]

Description: This budget contains, for each channel, best estimates of:

a) the fractional transmission ('throughput'), averaged over the passband, of each component in the optical train from the instrument entrance pupil to the detector

b) the resulting overall 'throughput', including chopping factor

c) the NEN allocation (from the INSTRNEN Budget), normalised for unit signal bandwidth, for the specified spectral interval, and referred to the detector input

d) the background flux incident on the detector, and the resulting background contribution to the total noise at the detector output

e) the maximum detector NEP and minimum Responsivity required to achieve the required signal to noise ratio (SNR)

f) the specified maximum detector NEP and minimum Responsivity, and the corresponding performance margin (defined as the ratio of predicted SNR to minimum required SNR)

This table shall be the definitive document for the above quantities, and will be updated whenever better estimates become available.

The OPDETPRE Budget summary table is on the following 4 sheets . . . . .

JGW/DMW Rev L 1997-05-28

This spreadsheet is part of TC-NCA-42, HIRDLS OPDETPRE Budget Description Document

CHAN #	Species	WAVELENGTH µm 50% low	WAVELENGTH µm 50% high	Spect. width %	Coher. length µm	Note k REFLEC M1 (SCANM) BOL Au-pltd	Note k REFLEC M2 (PARAB) BOL Au-pltd	Note k REFLEC M3 (ELLIP) BOL Au-pltd	Note k REFLEC M4 (PLANE) BOL Au-pltd	Note l TXMISSN WARM FILTERS BOL (total)	Note m TXMISSN LENS 1 SUBSTR.	Note n TXMISSN LENS 1 C'TINGS BOL	Note t TXMISSN WINDOW (ZnSe)	Note n TXMISSN WINDOW C'TINGS BOL	Note p TXMISSN LENS 2 SUBSTR.	Note n TXMISSN LENS 2 C'TINGS BOL	Note l TXMISSN COLD FILTERS BOL (total)	OPTICS THR'PUT BOL e/pupil to det.	Note r CHOPP'G FACTOR	Note s OVERALL THR'PUT BOL e/pupil to det.	CHAN #
1	N2O/Aero	17.01	17.76	4.34	400.00	0.988	0.988	0.988	0.988	0.71	0.598	0.76	0.843	0.83	0.598	0.76	0.72	0.070	0.405	0.029	1
2	CO2	16.26	16.67	2.47	666.67	0.988	0.988	0.988	0.988	0.64	0.835	0.84	0.861	0.89	0.835	0.84	0.72	0.165	0.405	0.067	2
3	CO2	15.65	16.39	4.64	344.83	0.987	0.987	0.987	0.987	0.81	0.802	0.90	0.872	0.93	0.802	0.90	0.73	0.237	0.405	0.096	3
4	CO2	15.15	15.97	5.29	294.12	0.987	0.987	0.987	0.987	0.82	0.771	0.96	0.891	0.97	0.771	0.96	0.76	0.280	0.405	0.113	4
5	CO2	14.71	15.27	3.75	400.00	0.987	0.987	0.987	0.987	0.81	0.825	1.00	0.920	1.00	0.825	1.00	0.77	0.371	0.405	0.150	5
6	Aero	11.96	12.18	1.81	666.67	0.986	0.986	0.986	0.986	0.78	0.889	1.00	0.942	1.00	0.889	1.00	0.75	0.411	0.405	0.167	6
7	CFC-11	11.72	11.98	2.13	555.56	0.986	0.986	0.986	0.986	0.80	0.888	1.00	0.942	1.00	0.888	1.00	0.76	0.427	0.405	0.173	7
8	HNO3	11.05	11.63	5.10	222.22	0.986	0.986	0.986	0.986	0.90	0.930	1.00	0.942	1.00	0.930	1.00	0.79	0.547	0.405	0.221	8
9	CFC-12	10.72	10.93	1.95	555.56	0.986	0.986	0.986	0.986	0.84	0.934	1.00	0.942	1.00	0.934	1.00	0.77	0.502	0.405	0.203	9
10	O3	9.90	10.10	2.00	499.95	0.985	0.985	0.985	0.985	0.85	0.937	1.00	0.942	1.00	0.937	1.00	0.77	0.509	0.405	0.206	10
11	O3	9.54	9.89	3.60	269.57	0.985	0.985	0.985	0.985	0.91	0.937	1.00	0.942	1.00	0.937	1.00	0.80	0.566	0.405	0.229	11
12	O3	8.77	8.93	1.77	500.00	0.985	0.985	0.985	0.985	0.86	0.937	1.00	0.942	1.00	0.937	1.00	0.77	0.514	0.405	0.208	12
13	Aero	8.20	8.33	1.65	500.00	0.985	0.985	0.985	0.985	0.85	0.937	1.00	0.942	1.00	0.937	1.00	0.77	0.508	0.405	0.206	13
14	N205	7.94	8.14	2.49	322.58	0.985	0.985	0.985	0.985	0.88	0.937	1.00	0.942	1.00	0.937	1.00	0.79	0.541	0.405	0.219	14
15	N20	7.80	7.96	2.05	384.62	0.985	0.985	0.985	0.985	0.85	0.937	1.00	0.942	1.00	0.937	1.00	0.79	0.523	0.405	0.212	15
16	ClONO2	7.70	7.82	1.63	476.19	0.985	0.985	0.985	0.985	0.81	0.937	1.00	0.942	1.00	0.937	1.00	0.78	0.492	0.405	0.199	16
17	CH4	7.30	7.55	3.34	222.22	0.985	0.985	0.985	0.985	0.88	0.937	1.00	0.942	1.00	0.937	1.00	0.80	0.548	0.405	0.222	17
18	H2O	6.97	7.22	3.55	200.00	0.985	0.985	0.985	0.985	0.86	0.937	1.00	0.942	1.00	0.937	1.00	0.80	0.536	0.405	0.217	18
19	Aero	7.06	7.13	0.99	714.29	0.985	0.985	0.985	0.985	0.62	0.937	1.00	0.942	1.00	0.937	1.00	0.75	0.362	0.405	0.147	19
20	H2O	6.49	7.03	8.10	83.33	0.985	0.985	0.985	0.985	0.90	0.937	1.00	0.942	1.00	0.937	1.00	0.82	0.574	0.405	0.233	20
21	NO2	6.12	6.32	3.23	192.31	0.985	0.985	0.985	0.985	0.81	0.937	1.00	0.942	1.00	0.937	1.00	0.80	0.505	0.405	0.204	21

In above table: Actual Value = Given Value * [xxx]
where [xxx] is the multiplier shown in the column header

Notes:

a Watts/(m^2*sr) from DSS Allocation in INSTRNEN Budget Rev. F (7.5 Hz noise bandwidth)
b Noise in previous column divided by sqrt(bw)
c Allocated noise converted to Watts by multiplying by A•ž,
  based on entrance pupil diameter and IFOV angles from constants table
d Background photon noise power at detectors = (photon rate) • (photon energy) = (ph. rate) • hc/(mean lambda) =
  = (ph. rate) • 1E+6 • hc/(mean lambda[microns])
e Background flux with chopper closed, from TC-LIR-34, Col. 27; based on obs. optical layout; TO BE REVISED
f Based on photon flux density and detector area calculated from dimensions in constants table
g Previous column multiplied by overall throughput figure
h D* = sqrt(detector area in cm^2)/(NEP in W/¦Hz)
j R = x(nV out) / (nW in) where x is calculated so that a preamp input noise of np nV/¦Hz,
  is allowed to add npa% to the detector output noise [i.e. (x)^2 + (np)^2 = ((1+npa/100)•x)^2].
k Mirror Coatings: BOL & EOL Au data from SSG on 941219.

This spreadsheet is part of TC-NCA-42, HIRDLS OPDETPRE Budget Description Document

Note k	Note k	Note k	Note k	Note l	Note m	Note n	Note t	Note n	Note p	Note n	Note l		Note r	Note s
REFLEC M1 (SCANM) **EOL** Au-pltd	REFLEC M2 (PARAB) **EOL** Au-pltd	REFLEC M3 (ELLIP) **EOL** Au-pltd	REFLEC M4 (PLANE) **EOL** Au-pltd	TXMISSN WARM FILTERS **EOL** (total)	TXMISSN LENS 1 SUBSTR.	TXMISSN LENS 1 C'TINGS **EOL**	TXMISSN WINDOW (ZnSe)	TXMISSN WINDOW C'TINGS **EOL**	TXMISSN LENS 2 SUBSTR.	TXMISSN LENS 2 C'TINGS **EOL**	TXMISSN COLD FILTERS **EOL** (total)	OPTICS THR'PUT **EOL** e/pupil to det.	CHOPP'G FACTOR	OVERALL THR'PUT **EOL** e/pupil to det.
0.976	0.976	0.976	0.976	0.68	0.598	0.76	0.843	0.83	0.598	0.76	0.68	0.060	0.405	0.024
0.976	0.976	0.976	0.976	0.62	0.835	0.84	0.861	0.89	0.835	0.84	0.68	0.144	0.405	0.058
0.976	0.976	0.976	0.976	0.78	0.802	0.90	0.872	0.93	0.802	0.90	0.69	0.205	0.405	0.083
0.976	0.976	0.976	0.976	0.79	0.771	0.96	0.891	0.97	0.771	0.96	0.71	0.243	0.405	0.098
0.975	0.975	0.975	0.975	0.78	0.825	1.00	0.920	1.00	0.825	1.00	0.72	0.319	0.405	0.129
0.974	0.974	0.974	0.974	0.73	0.889	1.00	0.942	1.00	0.889	1.00	0.71	0.345	0.405	0.140
0.974	0.974	0.974	0.974	0.75	0.888	1.00	0.942	1.00	0.888	1.00	0.71	0.358	0.405	0.145
0.974	0.974	0.974	0.974	0.86	0.930	1.00	0.942	1.00	0.930	1.00	0.74	0.468	0.405	0.189
0.974	0.974	0.974	0.974	0.79	0.934	1.00	0.942	1.00	0.934	1.00	0.72	0.423	0.405	0.171
0.973	0.973	0.973	0.973	0.80	0.937	1.00	0.942	1.00	0.937	1.00	0.72	0.429	0.405	0.174
0.973	0.973	0.973	0.973	0.87	0.937	1.00	0.942	1.00	0.937	1.00	0.75	0.485	0.405	0.196
0.973	0.973	0.973	0.973	0.81	0.937	1.00	0.942	1.00	0.937	1.00	0.72	0.434	0.405	0.176
0.973	0.973	0.973	0.973	0.80	0.937	1.00	0.942	1.00	0.937	1.00	0.72	0.428	0.405	0.173
0.973	0.973	0.973	0.973	0.84	0.937	1.00	0.942	1.00	0.937	1.00	0.74	0.462	0.405	0.187
0.973	0.973	0.973	0.973	0.82	0.937	1.00	0.942	1.00	0.937	1.00	0.74	0.451	0.405	0.183
0.973	0.973	0.973	0.973	0.75	0.937	1.00	0.942	1.00	0.937	1.00	0.73	0.407	0.405	0.165
0.973	0.973	0.973	0.973	0.84	0.937	1.00	0.942	1.00	0.937	1.00	0.75	0.468	0.405	0.190
0.972	0.972	0.972	0.972	0.83	0.937	1.00	0.942	1.00	0.937	1.00	0.75	0.461	0.405	0.187
0.972	0.972	0.972	0.972	0.59	0.937	1.00	0.942	1.00	0.937	1.00	0.71	0.307	0.405	0.124
0.972	0.972	0.972	0.972	0.86	0.937	1.00	0.942	1.00	0.937	1.00	0.77	0.489	0.405	0.198
0.972	0.972	0.972	0.972	0.78	0.937	1.00	0.942	1.00	0.937	1.00	0.75	0.433	0.405	0.175

l Warm Filter data: from JGW on 950704 based on information from RDU.
   Cold Filter data: BOL from RDU on 941011. EOL = BOL less 6% degradation allowance (each filter)
m From transmission calculation block (Col. 56), excludes effect of absorption in coatings
n Estimated less-than-unity transmission (both surfaces) due to absorption in AR coatings
p From transmission calculation block (Col. 63), excludes effect of absorption in coatings
r Taken to be 90% of ¦2/pi
s Result of multiplying together all the preceding columns in this block
t From transmission calculation block (Col. 59), excludes effect of absorption in coatings
u Based on 'generic target spec' figures for Responsivity and D*, and LIRIS-calculated background flux.
   Assumes 70% quantum efficiency
v Detector noise and D* figures in these columns assume that the photon BACKGROUND noise is INCLUDED.
w If the detectors and preamps are supplied from same source, detector and preamp noise allocations
   may be traded within the specified total of 2.88 nV/rt.Hz
x This margin is the ratio of resulting SNR divided by the computed IRD spec SNR.
y 65 K D* and R predictions from LMIRIS Marion Reine memo of 1997-04-08
z Amount in % by which the actual RMS noise voltage at the detector output exceeds what it would be
   in the absence of background photon noise
aa 60 K D* and R predictions from Frank Adams' Detector Model spreadsheet, Version 5

	Note a	Note b	Note c	Note g	Note e	Note f	Note d		Note h	Note j
CHAN	ALLOCATED NOISE RAD at e/pupil 1.00E-04	ALLOCATED NOISE RAD/¦Hz at e/pupil 1.00E-04	ALLOCATED NOISE POWER at e/pupil	ALLOCATED NOISE POWER at detector	BACKG'ND FLUX dens at det.	BACKG'ND FLUX at det.	BACKG'ND PWR on detector	CHAN	**MIN DET D* 1.00E+10**	**MIN DET RESP'VITY**
#	W/(m^2•sr)	W/(m^2•sr•¦Hz)	nW/¦Hz	nW/¦Hz	ph/(m^2•s)	ph/s	W	#	**cm•¦Hz/W**	**kV/W**
1	11.87	4.334	8.65E-03	2.47E-04	1.19E+20	7.93E+12	9.06E-08	1	**10.48**	**10.61**
2	6.23	2.275	4.54E-03	3.04E-04	5.13E+19	3.43E+12	4.14E-08	2	**8.50**	**8.60**
3	5.82	2.125	4.24E-03	4.07E-04	7.64E+19	5.11E+12	6.34E-08	3	**6.35**	**6.43**
4	5.90	2.154	4.30E-03	4.88E-04	1.28E+20	8.59E+12	1.10E-07	4	**5.30**	**5.37**
5	4.18	1.526	3.05E-03	4.57E-04	5.33E+19	3.57E+12	4.73E-08	5	**5.66**	**5.73**
6	1.86	0.679	1.36E-03	2.26E-04	1.34E+19	8.96E+11	1.47E-08	6	**11.45**	**11.59**
7	1.94	0.708	1.41E-03	2.44E-04	1.48E+19	9.88E+11	1.66E-08	7	**10.59**	**10.72**
8	4.08	1.490	2.97E-03	6.59E-04	3.55E+19	2.37E+12	4.16E-08	8	**3.93**	**3.98**
9	1.94	0.708	1.41E-03	2.87E-04	8.78E+18	5.87E+11	1.08E-08	9	**9.00**	**9.11**
10	1.37	0.500	9.99E-04	2.06E-04	7.72E+18	5.17E+11	1.03E-08	10	**12.57**	**12.73**
11	2.18	0.796	1.59E-03	3.64E-04	1.20E+19	8.01E+11	1.64E-08	11	**7.10**	**7.18**
12	0.67	0.245	4.88E-04	1.02E-04	5.72E+18	3.83E+11	8.59E-09	12	**25.42**	**25.74**
13	0.95	0.347	6.92E-04	1.43E-04	4.78E+18	3.20E+11	7.69E-09	13	**18.15**	**18.37**
14	0.89	0.325	6.49E-04	1.42E-04	6.22E+18	4.17E+11	1.03E-08	14	**18.20**	**18.42**
15	1.03	0.376	7.51E-04	1.59E-04	4.27E+18	2.85E+11	7.19E-09	15	**16.28**	**16.48**
16	1.06	0.387	7.73E-04	1.54E-04	3.42E+18	2.29E+11	5.85E-09	16	**16.82**	**17.02**
17	1.09	0.398	7.94E-04	1.76E-04	7.51E+18	5.02E+11	1.34E-08	17	**14.67**	**14.85**
18	1.09	0.398	7.94E-04	1.72E-04	6.37E+18	4.26E+11	1.19E-08	18	**15.01**	**15.19**
19	1.28	0.467	9.33E-04	1.37E-04	1.66E+18	1.11E+11	3.12E-09	19	**18.92**	**19.15**
20	1.59	0.581	1.16E-03	2.69E-04	1.03E+19	6.89E+11	2.03E-08	20	**9.60**	**9.72**
21	1.07	0.391	7.80E-04	1.59E-04	3.73E+18	2.49E+11	7.96E-09	21	**16.23**	**16.43**

				ITS Requirements				"EXPECTED" @ 60 K				"EXPECTED" @ 65 K			
Note u	Note z								Note aa	Note aa	Note x		Note y	Note y	Note x
BACKG'ND NOISE at det o/p	B/G NOISE	Bose-Einstein factor f(T,λ)	CHAN	D* @ 65 K 1.00E+10	NEP' @ 65 K	R @ 65 K	MARGIN	NEP'	D* 1.00E+10	R	MARGIN AT BOL	NEP'	D* 1.00E+10	R	MARGIN AT BOL
nV/¦Hz	%		#	cm•¦Hz/W	nW/¦Hz	kV/W		nW/¦Hz	cm•¦Hz/W	kV/W		nW/¦Hz	cm•¦Hz/W	kV/W	
0.844	5.6	1.07E+00	1	10.48	2.47E-04	10.61	**1.00**	1.43E-04	18.1	42.10	**1.9**	1.71E-04	15.1	26.70	**1.5**
0.473	1.7	1.06E+00	2	8.50	3.04E-04	8.60	**1.00**	1.04E-04	24.8	42.80	**3.1**	1.30E-04	19.9	35.40	**2.5**
0.442	1.5	1.05E+00	3	6.35	4.07E-04	6.43	**1.00**	1.15E-04	22.4	41.20	**3.8**	1.41E-04	18.3	32.50	**3.1**
0.491	1.8	1.05E+00	4	5.30	4.88E-04	5.37	**1.00**	1.20E-04	21.6	40.20	**4.3**	1.47E-04	17.6	31.20	**3.5**
0.350	0.9	1.04E+00	5	5.66	4.57E-04	5.73	**1.00**	8.62E-05	30.0	43.30	**5.6**	1.06E-04	24.5	43.80	**4.6**
0.436	1.4	1.02E+00	6	11.45	2.26E-04	11.59	**1.00**	5.03E-05	51.4	76.70	**4.7**	5.39E-05	48.0	86.40	**4.5**
0.431	1.4	1.02E+00	7	10.59	2.44E-04	10.72	**1.00**	5.33E-05	48.5	77.20	**4.8**	5.69E-05	45.5	84.80	**4.6**
0.259	0.5	1.01E+00	8	3.93	6.59E-04	3.98	**1.00**	6.03E-05	42.9	77.60	**11.6**	8.98E-05	28.8	54.30	**7.8**
0.308	0.7	1.01E+00	9	9.00	2.87E-04	9.11	**1.00**	4.82E-05	53.7	71.40	**6.2**	6.26E-05	41.3	77.40	**4.9**
0.436	1.4	1.01E+00	10	12.57	2.06E-04	12.73	**1.00**	4.89E-05	52.9	63.90	**4.3**	5.46E-05	47.4	75.60	**4.0**
0.315	0.7	1.01E+00	11	7.10	3.64E-04	7.18	**1.00**	5.79E-05	44.7	58.80	**6.5**	8.77E-05	29.5	59.30	**4.5**
0.856	5.8	1.00E+00	12	25.42	1.02E-04	25.74	**1.00**	4.56E-05	56.7	74.10	**2.3**	5.34E-05	48.4	66.90	**2.0**
0.598	2.7	1.00E+00	13	18.15	1.43E-04	18.37	**1.00**	5.48E-05	47.2	44.60	**2.6**	4.68E-05	55.3	63.80	**3.1**
0.703	3.8	1.00E+00	14	18.20	1.42E-04	18.42	**1.00**	5.66E-05	45.7	42.50	**2.5**	5.74E-05	45.1	62.00	**2.6**
0.531	2.1	1.00E+00	15	16.28	1.59E-04	16.48	**1.00**	5.65E-05	45.8	41.50	**2.8**	5.92E-05	43.7	60.80	**2.8**
0.499	1.9	1.00E+00	16	16.82	1.54E-04	17.02	**1.00**	5.62E-05	46.0	41.40	**2.7**	5.42E-05	47.7	59.90	**2.9**
0.674	3.5	1.00E+00	17	14.67	1.76E-04	14.85	**1.00**	6.26E-05	41.3	41.00	**2.8**	7.07E-05	36.6	57.20	**2.6**
0.664	3.4	1.00E+00	18	15.01	1.72E-04	15.19	**1.00**	6.68E-05	38.7	35.50	**2.5**	7.15E-05	36.2	54.20	**2.5**
0.428	1.4	1.00E+00	19	18.92	1.37E-04	19.15	**1.00**	4.00E-05	64.7	54.50	**3.3**	4.20E-05	61.6	54.30	**3.2**
0.567	2.4	1.00E+00	20	9.60	2.69E-04	9.72	**1.00**	6.81E-05	38.0	46.00	**4.1**	9.76E-05	26.5	51.60	**3.0**
0.626	3.0	1.00E+00	21	16.23	1.59E-04	16.43	**1.00**	7.01E-05	36.9	29.90	**2.2**	6.25E-05	41.4	47.60	**2.6**

4.10 RADMETAC BUDGET SUMMARY [For detailed derivation see ref. 1.4.42]

Description: the RADMETAC budget allocates maximum acceptable error levels to all identified potential sources of systematic radiometric error. Systematic errors are those which are not reduced by integrating or averaging of signal channel data.

This budget is generally more complex than the "non-radiometric" error budgets for three reasons:

a) the allocated values are channel-dependent (as is the case for the random noise budgets);

b) the allocated values are in many cases derived from temperature errors, angle changes, etc which are wavelength- or time-dependent;

c) the two parts of the IRD requirement generally correspond to two classes of error (SLOPE & ZERO), i.e. there are in effect two separate parts to the RADMETAC Budget (although there is significant overlap)

For RADMETAC Budget table, see after RADMETAC Notes

Summary of RADMETAC Budget line items and assumed error source magnitudes:

[number in square brackets is relevant SPRAT para #]

Item #	Description	Magnitude, notes	s/syst	see note
0 [4.6.7]	IFC BB temperature error	70mK error, to include cal, temp uniformity, offsets, stability to EOL	IFC	1,7
1 [4.6.7]	IFC mirror temperature error	IFC paraboloid T error 0.25K based on emissivity 0.03	IFC	1
2 [4.6.7]	IFC BB/mirror temp. diff'nce	Max 1K T diff BB/paraboloid, error in emissivity of 0.01	IFC	1,7
3 [4.6.4]	Deficit IFC BB emissivity	Effective emissivity 0.997 includes some stray light	IFC	2,3
4 [4.4.7.4]	Rad'metric offset: telescope	Rate of change of telescope mirrors: 5mK in 10 sec	TSS	1
5 [3.4.4.1]	Gain stability	Rate of change of gain 2E-4 in 10 sec, to include chopping efficiency, throughput, det. responsivity, electronic gain	TSS DSS IPS	1 1 1

6 Spectral calibration error [PLCR]	1 cm^-1 spectral error and 5K diff. between BB and std T	IFC	1,7
7 Scan stray: scan mir T gradt [?]	Av. temp of beam footprint changes 10mK (El), 100mK (Az)	TSS	1,9
8 Scan stray: x term [3.12.2.2 & ?]	x=1.5E-4, known to 20%	TSS	1
9 Scan stray: y & z terms [3.12.1.3]	Initial estimate based on TC-RAL-043B	TSS	2,4
10 Scan stray: x' term [3.12.2.2 & ?]	x'=1E-3 scan mir T within 4K of IFC BB	TSS	1
11 Scan stray: y'& z' terms [3.12.1.3]	Effective coeff = 2E-4 Radiance ratio = 0.5	TSS	2,4
12 Scan stray: diffraction	Initial estimate based on TC-RAL-043B	TSS	2,5
13 Uncorrected non-linearity [4.7.3.2.3.1.3]	0.1% slope error	DSS, IPS CAL	2,6 2
14 Electronic offset change [4.7.3.2.3.1.2]	Change over 10 sec: NEN/4/sqrt(12) cts	IPS	1
15 Synchronous jitter [4.4.10.2.3]	Jitter = 1 microradian = 0.2 arc sec = 3 m at limb	TSS	1

/ RADMETAC Notes . . . . .

Notes
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1. No further analysis required at this time. Appropriate radiometric error allocated to subsystem(s)
2. Further analysis required. Provisional radiometric error allocated to subsystem(s)
3. The IFC BB effective emissivity also controls the IFC paraboloid scatter spec. The RAL stray light model will guide this spec. and the derived contamination spec.
4. The RAL stray light model will guide these requirements and the derived contamination spec
5. Subject to revision if improved diffraction data becomes available
6. Analysis of radiation effects on signal processing electronics is required to determine whether this requirement is appropriate, and what level of shielding is implied.
7. Assumed emissivity and/or spectral values and/or errors to be determined as part of Pre-launch Calibration process
8. One error source not included here is polarization of the IFC view. Very simple calculations indicate that the effect is orders of magnitude too small to worry about, but a better analysis would be valuable. Further work on RADMETAC includes taking account of these analyses when available, and further study of the best way to treat the scan stray components of the error budget, which may at present be overestimated
9. These figures correspond to a maximum temperature gradient across the composite illuminated area of the scan mirror of 2 degrees across any diameter

RADMETAC BUDGET: SLOPE ERRORS (in percent)

Last Changed: 950405

SOURCE	CHANNEL > 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
IFC BB temperature error	0.07	0.08	0.08	0.08	0.08	0.10	0.10	0.11	0.11	0.12	0.12	0.14	0.15	0.15	0.15	0.15	0.16	0.17	0.17	0.18	0.19
IFC mirror temp. error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
IFC BB/mirror temp. diff	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
Deficit IFC BB emissivity	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Radiometric offset change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gain stability	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Spectral calibration error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scan Stray: Scan mirr.av.T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scan Stray: x term	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scan Stray: x' term	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scan Stray: y',z' terms	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scan Stray: Diffraction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uncorrected non-linearity	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Electronic offset change	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Synchronous jitter	0.06	0.03	0.04	0.05	0.05	0.17	0.14	0.13	0.14	0.08	0.06	0.11	0.15	0.09	0.05	0.04	0.08	0.15	0.18	0.09	0.08
TOTAL (RMS)	0.25	0.24	0.24	0.24	0.24	0.30	0.28	0.28	0.29	0.27	0.26	0.28	0.31	0.29	0.28	0.28	0.29	0.32	0.34	0.30	0.31
TOTAL (SUM)	0.60	0.56	0.57	0.58	0.58	0.72	0.70	0.69	0.71	0.66	0.65	0.71	0.77	0.71	0.68	0.67	0.72	0.79	0.84	0.75	0.76
REQUIREMENT	1.00	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

RADMETAC BUDGET: ZERO ERRORS (in NENs)

Last Changed: 950405

SOURCE	CHANNEL > 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Radiometric offset change	0.01	0.02	0.03	0.04	0.04	0.06	0.07	0.16	0.06	0.09	0.10	0.12	0.10	0.14	0.11	0.09	0.16	0.15	0.04	0.24	0.11
Gain stability	0.02	0.02	0.05	0.05	0.05	0.06	0.07	0.16	0.06	0.08	0.09	0.10	0.07	0.10	0.08	0.06	0.10	0.10	0.03	0.14	0.06
Scan Stray: Scan mirr.av.T	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.11	0.05	0.06	0.07	0.09	0.07	0.10	0.08	0.06	0.11	0.11	0.03	0.17	0.08
Scan Stray: x term	0.10	0.11	0.23	0.26	0.26	0.31	0.34	0.78	0.31	0.40	0.43	0.48	0.35	0.50	0.39	0.30	0.51	0.48	0.13	0.72	0.31
Scan Stray: y and z terms	0.01	0.01	0.01	0.02	0.03	0.11	0.13	0.32	0.13	0.13	0.07	0.25	0.17	0.16	0.07	0.04	0.11	0.12	0.04	0.14	0.07
Scan Stray: Diffraction	0.04	0.03	0.06	0.07	0.08	0.23	0.25	0.58	0.23	0.19	0.10	0.28	0.17	0.15	0.06	0.04	0.09	0.09	0.03	0.09	0.04
Electronic offset change	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Synchronous jitter	0.03	0.03	0.04	0.04	0.04	0.06	0.03	0.07	0.04	0.07	0.05	0.05	0.03	0.04	0.04	0.04	0.03	0.02	0.11	0.03	0.02
TOTAL (RMS)	0.13	0.14	0.26	0.29	0.30	0.42	0.47	1.06	0.42	0.49	0.49	0.64	0.45	0.59	0.44	0.34	0.58	0.55	0.20	0.81	0.37
TOTAL (SUM)	0.28	0.30	0.52	0.58	0.60	0.95	1.01	2.24	0.95	1.08	1.00	1.43	1.03	1.26	0.91	0.70	1.18	1.14	0.47	1.60	0.77
REQUIREMENT	1.00	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

4.11 RADCALAC BUDGET SUMMARY [For detailed derivation and plots, see ref. 1.4.44]

Traceability: IRD: 2.5.1

SPRAT: none explicitly

ITS: none explicitly

Description: the RADCALAC budget allocates target error levels to identified potential sources of systematic error in the pre-launch radiometric calibration equipment. Systematic errors are those which are not reduced by integrating or averaging of signal channel data.

This budget is generally more complex than the "non-radiometric" error budgets for three reasons:

a) the allocated values are channel-dependent (as is the case for the random noise budgets);

b) the allocated values are in many cases derived from temperature errors, angle changes, etc which are wavelength- or time-dependent;

c) the two parts of the IRD requirement generally correspond to two classes of error (SLOPE & ZERO), i.e. there are in effect two separate parts to the RADCALAC Budget (although there is significant overlap)

d) this budget does not flow down via the ITS to yield instrument requirements, but flows down into the pre-launch calibration accuracy requirements

For RADCALAC Budget table, see next sheet

RADCALAC BUDGET: SLOPE ERRORS (in percent)

SOURCE CHANNEL >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
EBB temperature error	0.14	0.14	0.18	0.18	0.18	0.19	0.19	0.23	0.18	0.20	0.20	0.20	0.19	0.21	0.20	0.19	0.21	0.21	0.16	0.22	0.20
EBB emissivity error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
EBB baseplate T uniformity	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
EBB side T uniformity	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
Spectral calibration error	0.27	0.26	0.31	0.31	0.30	0.27	0.27	0.31	0.24	0.24	0.24	0.21	0.20	0.20	0.18	0.17	0.18	0.17	0.13	0.18	0.14
TOTAL (SUM)	0.45	0.45	0.55	0.56	0.54	0.51	0.52	0.61	0.48	0.50	0.50	0.48	0.45	0.47	0.44	0.42	0.46	0.44	0.35	0.48	0.40
REQUIREMENT	1.00	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

RADCALAC BUDGET: ZERO ERRORS (in NENs)

SOURCE CHANNEL >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
EBB temperature error	0.14	0.14	0.18	0.18	0.18	0.19	0.19	0.23	0.18	0.20	0.20	0.20	0.19	0.21	0.20	0.19	0.21	0.21	0.16	0.22	0.20
SBB temperature error	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EBB baseplate T uniformity	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
EBB side T uniformity	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
EBB/SBB emissivity diff.	0.04	0.05	0.11	0.12	0.12	0.12	0.14	0.33	0.14	0.22	0.30	0.31	0.11	0.12	0.10	0.07	0.13	0.13	0.03	0.20	0.09
EBB/SBB i/p radiance diff.	0.04	0.05	0.11	0.12	0.12	0.12	0.14	0.33	0.14	0.22	0.30	0.31	0.11	0.12	0.10	0.07	0.13	0.13	0.03	0.20	0.09
Spectral calibration error	0.23	0.27	0.27	0.27	0.30	0.22	0.23	0.22	0.22	0.20	0.19	0.22	0.15	0.19	0.18	0.16	0.17	0.17	0.12	0.14	0.13
TOTAL (SUM)	0.50	0.56	0.73	0.75	0.78	0.71	0.75	1.17	0.73	0.89	1.04	1.09	0.62	0.70	0.62	0.55	0.70	0.68	0.39	0.81	0.56
REQUIREMENT	1.00	0.50	0.50	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

4.12 PLACEXTL BUDGET

Description: This budget defines maximum allowable values to the errors in in-orbit PLACEMENT of the instrument boresight, and allocates these between error sources INTERNAL to the instrument and error sources EXTERNAL to the instrument.

The figures in the following table relate to maximum error with respect to the SRCF and the IRCF. When the initial alignment processes are carried out, allowances must be made to account for the ACTUAL (measured) orientations of the IAC relative to the IRCF, and the SMRC relative to the ORCF

R(X) = roll (about X axis); P(Y) = pitch (about Y axis);
Y(Z) = yaw (about Z axis); Figures are arc seconds (3 sigma)

ITEM	PLACEMENT			SPRAT PARA
	R(X)	P(Y)	Y(Z)	
INTERNAL - alignment of boresight to IRCF:	300	300	360	2.7.13
++EXTERNAL - alignment of IRCF to SRCF:	180	180	360	2.7.13
Arithmetic sum:	480	480	720	
Requirement:	480	480	720	2.7.12

++ breakdown of external allocation will be determined by S/C contractor and will be recorded on Mechanical Interface Control Drawing for HIRDLS

4.13 PLACINTL BUDGET

Description: This budget allocates the total allowable in-orbit INTERNAL PLACEMENT errors in arc seconds (3 sigma):

R(X) = roll (rotation about X axis);
P(Y) = pitch (rotation about Y axis);
Y(Z) = yaw (rotation about Z axis);

DESCRIPTION	PLACEMENT			see note	SPRAT PARA
	R(X)	P(Y)	Y(Z)		
Instrument Boresight to TRCF:	n/a	60	60	1	2.7.14
Scan mirror azimuth axis to TRCF:	60	60	n/a	1	2.7.15
TRCF to IRCF:	240	240	300	2	2.7.16
Arithmetic sum:	300	300	360		
PLACEXTL Budget requirement:	300	300	360		2.7.13

Notes

1. these two budget items are independent and have been separately summed into the total line
2. these numbers shall be achieved, given the use of compliant mounts at the OB/Baseplate interface

4.14 POINTELV BUDGET

Description: The following budget allocates to appropriate instrument subsystems maximum allowable errors contributing to the uncertainty in the KNOWLEDGE of relative ILOS elevation angle at EOL between radiance signal data samples over the stated time periods, AFTER any relevant CALIBRATION and/or GROUND DATA PROCESSING of the Flight Data. See notes for comments on corresponding instrument subsystem hardware requirements (if applicable).

The term 'PLPF' refers to the "Pointing low-pass filter"; see 1.4.36

Col A: gives the random error allocation (arc seconds, 3-sigma, referred to the PLPF bandwidth) for time periods from 25ms to 10 seconds, for any scan elevation setting, and assuming no change in azimuth scan setting;

Col B: gives the random error allocation (arc seconds, 3-sigma, referred to the PLPF bandwidth) for time periods between 10 seconds and 66 seconds, and between 1 orbit - 132 secs and 1 orbit + 132 secs, for any scan elevation or azimuth setting;

Col C: gives the systematic maximum error allocation (percent) for relative ILOS elevation angles above 0.04 degrees and over a single elevation scan;

Col D: gives the systematic maximum error allocation (arc seconds) for relative ILOS elevation angles below 0.04 degrees and over a single elevation scan.

ELEVATION ANGLE	A 3-sig <10sec	B 3-sig >10sec	SINGLE ELEV SCAN C syst'c >.04dg	D syst'c <.04dg	see Note	SPRAT PARA
Retrieved Gyro relative) pitch attitude error with) respect to inertial space)	1.2	2.2				2.7.21
			0.09%	0.12		2.7.25
Error in ILOS elevation) pointing knowledge) relative to Gyro)	1.2	2.75			1,2	2.7.23
			0.15%	0.20	1	2.7.25
Allowance for effects of (unmeasurable) ILOS jitter on pointing knowledge:	0.15	n/a	0.01%	0.03	3,4	
"Geometric" sum:	2.1"	4.2"	-	-	5	
Arithmetic sum:	-	-	0.25%	0.35"		
IRD Limit:	2.1"	4.2"	0.25%	0.35"		2.7.17

/Notes on POINTELV Budget . . . .

Notes
-----

1. This item IN PRINCPLE includes, but may not be limited to, uncertainty in the knowledge of (i) POA elevation angle relative to the scanner elevation datum or TRCF, (ii) scan mirror elevation angle (after encoder calibration) relative to the scanner elevation datum; (iii) the elevation error due to scanner elevation axis tilt and tilt changes about instrument roll axis; (iv) elevation error due to an absolute azimuth scan angle knowledge error (see TC-OXF-28B) [see Note 2]. In each case allowance should be made for any legitimate correction for OB or other thermal distortion.

2. 0.2 arc sec is contributed by a relative azimuth scan angle ILOS knowledge error of 20 arc sec [see note 3 of the POINTAZM Budget]

3. The figure in col A is that allowed for "integrated vertical ILOS jitter" as defined in ref. 1.4.36. Note that this needs to include the effects of azimuth jitter coupled into the elevation axis at large azimuth scan angles (see TC-OXF-28B)

   The figure in col D is that allowed for "integrated synchronous vertical ILOS jitter" as defined in ref. 1.4.36

   The figure in col C is expressed in percent, but strictly the jitter requirement has the same constant value for angles above 0.04 degrees (ref 1.4.36). This can be revised if necessary but the number is so small that it is thought unlikely to become an issue.

4. The word "unmeasurable" is significant. To the extent that any ILOS vertical jitter may be measured and corrected for, the figure in this table may be taken to apply to the residual, uncorrectable jitter. Variations of OB pointing referred to the GMU/OB interface and within the bandwidth of the PLPF may be considered measurable by the Gyro Subsystem.

5. Since there may be some degree of correlation between these items, the "geometric sum" has been used to reconcile the budget total with the IRD figure. The "geometric sum" is the geometric mean of the arithmetic sum and the root-square sum

4.15 POINTAZM BUDGET

Description: The following budget allocates to appropriate instrument Subsystems maximum allowable errors at EOL which contribute to the uncertainty in the KNOWLEDGE of the 'absolute' ILOS azimuth angle of any radiance signal data sample, and of the 'relative' mean ILOS azimuth angle between data sets with different azumuth settings. In this context 'absolute' means true azimuth angle w.r.t. the orbit plane, and 'relative' is w.r.t. time.

In the table below, RELATIVE means azimuth knowledge to within the specified accuracy is required between any two elevation scans within a 66-second scan cycle, and between spatially adjacent elevation scans on consecutive orbits, i.e. separated in time by 1 orbit +/- 132 seconds. 'Mean' means averaged over a single elevation scan.

ERROR SOURCE	Total error (arc sec) RELATIVE	ABSOLUTE	see Note	SPRAT PARA
Retrieved Gyro relative yaw attitude error with respect to inertial space:	62	n/a		2.7.21
Error in ILOS azimuth pointing knowledge relative to Gyro:	72	90++	1,2	2.7.23
Allowance for the effects of ILOS jitter on pointing knowledge:	10	5	3	
Error in knowledge of IRCF alignment with respect to the SRCF:	n/a	180		2.7.27
Error in knowledge of TRCF alignment with respect to the IRCF:	n/a	265	4	2.7.27
Arithmetic sum:	144	540		
IRD Requirement:	144	540 (max)		2.7.19

++ this really refers to the accuracy with which the azimuth component of the BORESIGHT direction is measured with respect to the TRCF X-Z plane.

/Notes on POINTAZM Budget . . . .

Notes
-----

1. this item includes, but may not be limited to, uncertainty in knowledge of:
   - (i) scan mirror azimuth angle relative to the scanner azimuth datum [see Note 2]
   - (ii) POA azimuth angle relative to the scanner datum/TRCF/GMU
   - (iii) scanner azimuth datum relative to the TRCF/GMU

2. Uncertainty in the knowledge of scan mirror azimuth angle relative to the scan datum couples into the POINTELEV Budget (TC-OXF-28B). The "notional allowance" (worst case) for this in the POINTELV Budget (see note 2 of POINTELV) corresponds to an azimuth scan angle uncertainty of 20 arcsec ILOS, which is part of the 72 arc sec in the second line of the above table.

3. This is the allowance for "integrated azimuth ILOS jitter" as defined in ref. 1.4.36. Included in this budget item is jitter of the azimuth scan angle relative to the scan datum (see TC-OXF-28B) which couples into the POINTELV Budget (see note 3 of POINTELV).

4. This fairly loose requirement reflects the fact that the OB will be mounted on compliant vibration isolators

4.16 COOLMARG BUDGET

Description: This budget is in four parts:
- A. DSS temperature table
- B. DSS heat load budget (estimated)
- C. Total (specified) heat lift budget
- D. Cooling margin summary table

Note:-
A "+" symbol indicates those parameters which are specified as requirements or limits in the ITS. The remaining numbers are intended for reference.

A. DSS temperature table

```
Detector temperature at which
                detector performance is specified:     65 K +

(Generous) allowance for T drop between
detector array and Cold Node* (including margin):    3.0 K

             SPECIFIED TEMPERATURE AT COLD NODE*:     62 K +
```

* The Cold Node is on the DSS side of the DSS/Cold Link interface joint

B. DSS heat load budget (estimated)

```
  Estimated heat input through DSS window:       19 mW

    Max. dissipation in detector elements:       50 mW

Estimated heat conducted through
                   electrical connections:       40 mW

Estimated additional heat conducted
                    from 300K environment:      371 mW

Estimated additional heat radiated
                    from 300K environment:      156 mW

  Max. dissipation in fine-control heater:       50 mW
                                                ------
Estimated total DSS heat load (no margin):      686 mW
                                                ------
```

/continued . . . .

C. Total (specified) heat lift budget

	(a)	(b)
Estimated total DSS heat load:	686 mW	686 mW
Specified minimum additional heat lift margin when Cooler operating within ...		
(a) +/- 1 Hz of optimum operating frequency:	84 mW	
(b) outside +/- 1 Hz window but within +/- 4 Hz window:		14 mW
SPECIFIED TOTAL REQUIRED COOLER HEAT LIFT: (@ 62 K Cold Node temperature)	770 mW+	700 mW+

D. Estimated actual cooling margin summary table

This table indicates the APPROXIMATE variation of (a) cryo heat lift, (b) Cold Node temperature, as a function of piston stroke (the latter expressed in percent of maximum safe stroke) for the HIRDLS Cooler.

Compressor input power and total CSS power consumption are also shown.

A STROKE %	B HEAT LIFT mW	C TEMP K	D COMPRSSR PWR (W)	E TOTAL CSS PWR (W)*	
70	539	69.3	20.7	55.7	
71	585	67.8	21.8	56.8	
72	632	66.4	23.0	58.0	
73	678	64.9	24.1	59.1	
74	724	63.5	25.3	60.3	
75	770	62.0	26.4	61.4	<---- nominal stroke
76	816	60.5	27.6	62.6	
77	862	59.1	28.7	63.7	
78	908	57.6	29.9	64.9	
79	955	56.2	31.0	66.0	
80	1000	54.7	32.2	67.2	

* includes 35 watts for Cooler electronics

At nominal stroke (75%), the specified heat lift of 770 mW @ 62K requires a total nominal input power of 61.4 watts.

The numbers in column B show the variation in "heat lift" at the Cold Node at various stroke settings for a constant Cold Node temperature of 62K. The numbers in column C show the variation in Cold Node temperature at various stroke settings for a constant Cold Node "heat lift" of 770 mW. In all cases the power input will vary as a function of stroke setting per the numbers in columns D and E.

Example: 80% stroke will provide:- 7 K lower detector temperature, OR 230 mW additional heat lift, OR a combination of the two; the power input will increase by approx. 6 watts.

SECTION 5

SPRAT FLOW-DOWN TRACEABILITY SUMMARY TABLE

SPRAT FLOW-DOWN TRACEABILITY SUMMARY TABLE

Note 1: The requirement flow-down is CATegorized as follows:

- D **Direct:** requirement flows directly from source doc. to dest. doc. without interpretation, modification or allocation
- X **eXplained:** requirement flows directly from source doc. to dest. doc. with some explanation which is documented in listed "other ref."
- SA **Allocated:** requirement flows via **SPRAT** because it needs to be allocated (decomposed) into two or more components
- SE **Engineering judgement:** requirement originates in **SPRAT** and flows down as shown
- SM **Modified:** requirement flows via **SPRAT** , in which some modification or interpretation may be included

Note 2: Source doc. requirements which are not listed in first column have not been addressed in this process; they flow DIRECTLY into a lower-level document

Note 3: (SPRAT) in parentheses indicates para. applies internally to SPRAT

Note 4: **BOLD** font in SPRAT BUDGET column indicates that this SPRAT para. refers to Budget input/total (i.e. bottom line)
PLAIN font in SPRAT BUDGET column indicates that this SPRAT para. refers to Budget output line item (i.e. allocation)

SOURCE/PARA		CAT	SPRAT PARA#	SPRAT BUDGET (note 4)	DESTINATION DOC. (note 3)	PARA#
		SE	2.7.12	**PLACEXTL**	(SPRAT)	
		SE	2.7.13	**PLACINTL**	(SPRAT)	
IRD	2.4.1	SM	2.5.1	**PASSBAND**	(SPRAT)	
IRD	2.4.2	SM	2.5.6	**SPECKNOW**	(SPRAT)	
IRD	2.4.3	SA	2.5.5	**BLOCKING**	(SPRAT)	
IRD	2.5.1	SM	2.6.6	**RADMETAC**	(SPRAT)	
IRD	2.6.2	SM	2.4.15	**OUTFIELD**	(SPRAT)	
IRD	2.6.3	SM	2.4.20	**IFOVKNOW**	(SPRAT)	
IRD	2.7.5	SM	2.7.17	**POINTELV**	(SPRAT)	
IRD	2.8.3	SM	2.7.19	**POINTAZM**	(SPRAT)	
IRD	2.7.5	SA	2.7.21	POINTELV	ATBD	
IRD	2.1.3	SM	2.2.3		ATBD	
IRD	2.7.5	SA	2.7.23	POINTELV	ATBD	
IRD	2.7.5	SA	2.7.25	POINTELV	ATBD	
IRD	2.1.2	SM	2.2.1		EID	1.7
IRD	2.1.3	SM	2.2.3		EID	3.7
GIRD	9.1	SM	2.2.5		EID	3.7
		SE	2.7.13	PLACEXTL	EID	3.5.1
IRD	2.1.1	D			EID	3.5.2
IRD	2.1.4	SM	2.2.7		EID	3.5.2
IRD	2.8.3	SA	2.7.27	POINTAZM	EID	3.5.3
		SE	2.7.3		GSE	
		SE	3.2.9		GSE	
		SE	3.4.1		GSE	

SOURCE/PARA		CAT	SPRAT	SPRAT BUDGET	DESTINATION DOC.	
			PARA#	(note 4)	(note 3)	PARA#
		SE	3.9.7		GSE	
		SE	3.9.15		GSE	
GIRD	9.1	SM	2.2.5		ITS	3.11
					ITS	3.11
					ITS	3.2
		SE	2.4.1		ITS	3.3
		SE	2.3.1		ITS	3.1.3
					ITS	3.11.12
					ITS	3.12.2.1
					ITS	3.12.2.2
					ITS	3.13.3
GIRD	4.2	SM	3.5.19	[was 3.5.3]	ITS	3.2.2
					ITS	3.2.X
IRD	2.6.1	SM	2.4.11	OPDETPRE	ITS	3.3.1
IRD	2.6.1	SM	2.4.11	OPDETPRE	ITS	3.3.2
IRD	2.6.3	SA	2.4.23	IFOVKNOW	ITS	3.3.3.1
IRD	2.6.3	SA	2.4.25	IFOVKNOW	ITS	3.3.3.2
IRD	2.6.1	SM	2.4.13	OPDETPRE	ITS	3.3.4
					ITS	3.3.5
		SE	2.6.3		ITS	3.3.7
IRD	2.4.2	SA	2.5.9	SPECKNOW	ITS	3.4.2
					ITS	3.4.4.1
IRD	2.5.6	SM	2.9.15		ITS	3.4.4.2
					ITS	3.4.4.2.1
IRD	2.5.1	SA	2.9.27	RADMETAC	ITS	3.4.4.2.1
					ITS	3.4.4.2.1
		SE	2.9.17		ITS	3.4.4.3
IRD	2.5.1	SA	2.9.28	RADMETAC	ITS	3.4.4.3.1
IRD	2.6.2	SA	2.9.29	OUTFIELD	ITS	3.4.4.5
		SE	2.9.7		ITS	3.4.4.6
		SE	2.9.6		ITS	3.4.4.7
					ITS	3.4.4.7
		SE	3.2.3		ITS	3.4.5
					ITS	3.4.5
IRD	2.5.3	SA	2.9.11	INSTRNEN	ITS	3.4.7.1
IRD	2.5.3	SA	2.9.11	OPDETPRE	ITS	3.4.5
					ITS	3.4.7.3.1
					ITS	3.4.8.1
IRD	2.5.2	SM	2.6.5		ITS	3.4.9
IRD	2.7.1	SM	2.8.17		ITS	3.5.1.1
					ITS	3.5.1.1
IRD	2.7.2	SM	2.8.19		ITS	3.5.1.2
					ITS	3.5.1.3
		SE	2.8.18		ITS	3.5.1.4
					ITS	3.5.1.4
IRD	2.8.1	SM	2.8.25		ITS	3.5.2 ??
IRD	2.8.2	SM	2.8.21		ITS	3.5.2.1
					ITS	3.5.2.1
					ITS	3.5.2.1
					ITS	3.5.2.3a
					ITS	3.5.2.3b

SOURCE/PARA		CAT	SPRAT	SPRAT BUDGET	DESTINATION DOC.	
			PARA#	(note 4)	(note 3)	PARA#
GIRD	3.5.2	SM	2.7.9		ITS	3.5.3.1
		SE	2.7.16	PLACINTL	ITS	3.5.3.2
IRD	2.8.3	SA	2.7.27	POINTAZM	ITS	3.5.3.2
					ITS	3.6.2.1
					ITS	3.6.6.1
					ITS	3.7.2.1
					ITS	3.7.7
UIID	3.3	SM	3.5.21	[was 3.5.5]	ITS	3.7.8
					ITS	3.7.8
					ITS	3.8.2
					ITS	3.8.2.1
		SE	3.9.19		ITS	4.2.2.1
		SE	2.6.31		ITS	4.2.3.2
		SE	2.6.33		ITS	4.2.3.3
		SE	3.3.17		ITS	4.2.3.5
IRD	2.7.5	SA	2.7.25	POINTELV	ITS	4.3.3.2.1
IRD	2.8.3	SA	2.7.21	POINTAZM	ITS	4.3.3.2.2
		SE	2.7.14	PLACINTL	ITS	4.4.10.1
					ITS	4.4.10.2.3
					ITS	4.4.10.2.3
IRD	2.8.1	SM	2.8.25		ITS	4.4.10.3
		SE	2.9.2	OPDETPRE	ITS	4.4.4.1.1
					ITS	4.4.4.1.2
		SE	2.7.15	PLACINTL	ITS	4.4.5.1.1
		SE	2.8.13		ITS	4.4.5.1.2
		SE	2.7.3		ITS	4.4.5.5
IRD	2.5.1	SA	2.6.20	RADMETAC	ITS	4.4.7.3
					ITS	4.4.7.3
IRD	2.5.1	SA	2.6.19	RADMETAC	ITS	4.4.7.4
					ITS	4.4.7.4
					ITS	4.4.7.5
		SE	3.7.5		ITS	4.5.6.4
		SE	2.8.23		ITS	4.6.3
IRD	2.5.1	SA	2.6.21	RADMETAC	ITS	4.6.4
		SE	2.6.29		ITS	4.6.7.1
IRD	2.5.1	SM	3.3.13	RADMETAC	ITS	4.6.7.2
IRD	2.5.1	SA	3.3.15	RADMETAC	ITS	4.6.7.2
					ITS	4.6.7.2
IRD	2.9	SM	3.4.2		ITS	4.7.3.2
		SE	3.8.1		ITS	4.7.3.2.10
		SE	2.9.3		ITS	4.7.3.2.2
		SE	2.8.27		ITS	4.7.3.2.3.2
IRD	2.10.4	SM	2.8.31		ITS	4.7.3.2.3.3
IRD	2.10.4	SM	3.3.21		ITS	4.7.3.2.3.4
		SE	3.3.11		ITS	4.7.4.1
		SE	3.4.3		ITS	4.7.5.1.2
		SE	2.9.19		ITS	4.7.3.2.3.1.3
		SE	2.9.21		ITS	4.7.3.2.3.1.3
		SE	3.2.9		ITS	
		SE	3.3.3		ITS	4.7.3.2.3
		SE	3.3.5		ITS	3.2.7

SOURCE/PARA		CAT	SPRAT	SPRAT BUDGET	DESTINATION DOC.	
			PARA#	(note 4)	(note 3)	PARA#
		SE	3.3.5		ITS	4.7.3.2.1.3
		SE	3.3.7		ITS	3.9.3.6.2
		SE	3.7.13		ITS	4.2.5.4
		SE	3.8.17		ITS	4.1.5.3.1
		SE	3.9.15		ITS	4.2.2.1
IRD	2.5.1	SA	2.6.35	RADMETAC	ITS	
IRD	2.5.1	SA	2.6.36	RADMETAC	ITS	
IRD	2.5.3	SA	2.6.38	INSTRNEN	ITS	4.4.4.1.1
IRD	2.5.8	SM	2.9.23		ITS	3.4.7.3.2
IRD	2.6.2	SA	2.4.16	OUTFIELD	ITS	
IRD	2.6.2	SA	2.4.17	OUTFIELD	ITS	
IRD	2.6.2	SA	2.4.18	OUTFIELD	ITS	
IRD	2.7.5	SA	2.7.21	POINTELV	ITS	
IRD	2.7.5	SA	2.7.23	POINTELV	ITS	
IRD	2.8.3	SA	2.7.23	POINTAZM	ITS	
IRD	2.2.1	X			ITS	
IRD	2.2.2	X			ITS	
IRD	2.2.3	X			ITS	
IRD	2.2.4	X			ITS	
IRD	2.2.5	X			ITS	
IRD	2.2.6	X			ITS	
IRD	2.3.2	D			ITS	
IRD	2.4.5	D			ITS	
IRD	2.5.4	D			ITS	
IRD	2.5.5	D			ITS	
IRD	2.5.9	D			ITS	
IRD	2.5.10	D			ITS	
IRD	2.8.4	D			ITS	
IRD	2.10.1	D			ITS	
IRD	2.10.5	D			ITS	
		SE	2.6.29		FOCD	
		SE	3.3.3		FOCD	
		SE	3.3.5		FOCD	
		SE	3.3.7		FOCD	
		SE	3.3.11		FOCD	
		SE	3.3.17		FOCD	
		SE	3.4.1		FOCD	
		SE	3.4.3		FOCD	
		SE	3.8.1		FOCD	
IRD	2.5.1	SA	3.8.15	RADMETAC	FOCD	
IRD	2.7.2	SM	2.8.19		FOCD	
IRD	2.8.1	SM	2.8.25		FOCD	
IRD	2.9	SM	3.4.2		FOCD	
		SE	2.4.1		PLCR	
		SE	2.7.3		PLCR	
		SE	2.8.18		PLCR	
		SE	3.2.5		PLCR	
		SE	3.8.25		PLCR	
		SE	3.9.19		PLCR	
IRD	2.4.2	SA	2.5.7	SPECKNOW	PLCR	
IRD	2.5.1	SA	2.6.7	RADMETAC	PLCR	

SOURCE/PARA		CAT	SPRAT	SPRAT BUDGET	DESTINATION DOC.	
			PARA#	(note 4)	(note 3)	PARA#
IRD	2.5.1	SA	2.6.23	RADCALAC	PLCR	
IRD	2.5.1	SM	3.3.13	RADMETAC	PLCR	
IRD	2.5.1	SA	3.3.15	RADMETAC	PLCR	
IRD	2.6.3	SA	2.4.21	IFOVKNOW	PLCR	
IRD	2.7.2	SM	2.8.19		PLCR	
IRD	2.7.5	SA	2.7.25	POINTELV	PLCR	
		SE	3.8.5		ITS	3.8.3.2
		SE	3.8.5		FOCD	
		SE	3.9.3	**CONTAMIN**	(SPRAT)	
		SE	3.9.5	CONTAMIN	ITS	3.12.2.1
		SE	3.9.5	CONTAMIN	PLCR	
		SE	3.9.5	CONTAMIN	EID	
		SE	3.5.1		ITS	3.2
		SE	3.5.1		FOCD	
		SE	3.5.3		ITS	3.2
		SE	3.5.3		FOCD	
		SE	3.5.5		ITS	3.2
		SE	3.5.5		FOCD	
GIRD	3.9	SE	3.5.17		ITS	3.2
		SE	3.9.19		ITS	3.12.6
		SE	3.9.21		GSE	
		SE	3.9.11		ITS	3.12.3
		SE	3.5.9		FOCD	
SPEC	4.5.3.2	SM	3.8.9		ITS	